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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND B. ALFRED RAWORTH.

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See page 101. 6455

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See Advertisement page 26. 6462

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See Advertisement page 46, June 7. 2403

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See half-page Advertisement page 30, June 14.

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PROFESSIONAL PRES.

The Council of the Chartered INSTITUTE of PATENT AGENTS by a resolution of the 4th day of June, 1918, authorised Fellows of the Institute to make, as from the 30th of June, 1918, an additional charge of 10 per cent. on the scales of fees recommended by the Council, to cover the additional expenses they have to incur in consequence of the war.

H. HOWGRAVE GRAHAM,
Secretary and Registrar. L 893

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The ELECTRICITY SUPPLY COMMITTEE of the Corporation of Dublin invite

Tenders for the Supply and Installation at their Pigeon House Works of a COAL CRUSHING PLANT, of a capacity of approximately 40 tons per hour. Full particulars, Specification, General Conditions and Form of Tender may be obtained from the City Electrical Engineer, Pigeon House Works, Dublin, on and after Thursday, June 27th, 1918.

Tenders, sealed and endorsed "Tender for Coal Crusher," must be addressed to "The Chairman, Electricity Supply Committee, Lord Edward Street, Dublin," and delivered there not later than Noon on Thursday, July 4th, 1918.

The Committee do not bind themselves to accept the lowest or any Tender.

FRED. J. ALLAN,
Secretary.

Electricity Supply Committee's Offices,
Lord Edward Street,
June 22nd, 1918. L 891

APPOINTMENTS OPEN.

DARLINGTON COUNTY BOROUGH.

TECHNICAL COLLEGE.

Principal of Technical COLLEGE WANTED. Commencing salary £460 per annum. Candidate must be a Graduate of a British University, with special qualifications in Physical and Engineering Sciences and must have had practical experience in Engineering work.—Forms of application may be obtained from the undersigned, and must be returned not later than July 6th, 1918.

A. C. BOYDE,
Education Office, Darlington, Secretary.
June, 1918. L 749

HUDDERSFIELD TECHNICAL COLLEGE.
Principal J. F. HUDSON, M.A., D.Sc.

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Further particulars on application to
T. THORP, Secretary. L 755

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Applications are Invited for the POST of TEACHER of ENGINEERING, duties to commence in September next. Commencing salary £250.

Forms of Application, which must be returned not later than July 5th, may be obtained from R. DEMPSEY, Clerk to the Governors, 1, Selborne Road, Walthamstow. L 875

Superintendent Engineer for large industrial works within 20 miles of London. Plant to be looked after is new and modern, embodying all latest improvements comprising conveying, crushing, hydraulic machinery, steam and electric power plant. Applicants having previous experience with plant running continuously 168 hours per week will receive special consideration. Expert chemists and allied technologists operate specialised departments. Salary commensurate with experience and ability of applicant.—Applications, stating full particulars of training and other experience, to be sent to L 762, Offices of ENGINEERING.

Chemist (Steelmaking) WANTED. Stock Converter Plant and Heroult Furnace. No person already on Government work will be engaged.—Apply, giving age, experience, salary required, and references, to your nearest EMPLOYMENT EXCHANGE, quoting No. A 5327. L 893

Works Manager Wanted by one of the largest manufacturers of heavy motor vehicles in the country. Experience in the latest methods of production is essential. No one on Government work will be engaged.—Address, giving fullest particulars of experience, with dates, age and salary expected, L 881, Offices of ENGINEERING.

Cost Clerks.—Wanted im- mediately in a large controlled Factory in East Midlands, two or three experienced men for Estimating Dept. Must be thoroughly conversant with reading and taking off quantities from drawings, etc. No person already on Government work will be engaged.—Apply, stating full particulars of experience, salary required, etc., to your nearest EMPLOYMENT EXCHANGE, mentioning No. A 5540. L 869

Clerk for Engineering Depart- ment of Controlled factory in Scotland. Typist, preferably, with experience in modern costing systems. Ineligible. No person already on Government work will be engaged.—Applicants must apply to their nearest EMPLOYMENT EXCHANGE, mentioning this Journal and L 872.

Cost and Order Clerk Re- QUIRED, with previous experience in engineering business; one used to tracings and simple drawings preferred, although this is not essential. No person engaged on Government work or residing more than 10 miles from London will be engaged.—Address, stating age, qualifications and salary expected, L 822, Offices of ENGINEERING.

Wanted, Correspondence CLERK, ineligible, with experience in machine and small tools, taps, grinding wheels, &c. Must be used to dictating and capable of taking charge of correspondence and experienced in similar work. State fully previous positions and wages required; Glasgow district.—Address, L 929, Offices of ENGINEERING.

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ELECTRICITY DEPARTMENT.

Applications are Invited from properly qualified men for the POSITION of ENGINEER-IN-CHARGE. Salary £175 per annum, rising by annual increments of £12 10s. to £300 per annum, plus war bonus of 20s. weekly and 12½ per cent. on earnings.

The appointment will be subject to one week's notice on either side.

Applications, stating experience and accompanied by copies of three recent testimonials, must be delivered to Mr. G. G. BELL, Engineer and Manager, Electricity Works, 85, Fulham Palace Road, Hammersmith, W. 6, not later than July 12th, 1918.

Canvassing will disqualify.

LESLIE GORDON,
Town Clerk.

Town Hall,
Hammersmith, W. 6.
26th June, 1918. L 930

ADMIRALTY.

DEPARTMENT OF ELECTRICAL ENGINEERING.

Electrical Engineer REQUIRED, with good experience in general electrical installations in Warships.

Apply, giving details of experience, stating age, salary required and forwarding copies of recent testimonials to the

DIRECTOR OF ELECTRICAL ENGINEERING,
Admiralty,
Great George Street,
London, S.W. 1. L 911

Assistant Works Manager WANTED for Marine Engineering Company on East Coast. Must be 6 o'clock man and capable of organising work (both new and repair) on up-to-date methods. No one on Government work need apply.—Apply your nearest EMPLOYMENT EXCHANGE, stating age, experience, and salary required, and mentioning No. A 5559. L 878

Required for Drawing Office of progressive Aircraft Works, a good MAN to act as Checker, able to take charge in chief Draughtsman's absence. Must be capable, in addition of getting out material, specifications, etc., if required. Good DRAUGHTSMAN also REQUIRED with jig and tool or aircraft experience. No one on Government work or living more than 10 miles away will be engaged.—Write BOX 565, SELLS, LTD., 168, Fleet Street, E.C. 4. L 917

Rate Fixer.—First-class Tool- room Rate Fixer REQUIRED, by a firm in the Midlands engaged on Aero Engine production. Applicants must have had a tool room experience of high-class work. No person already engaged on Government work will be engaged.—Apply to your nearest EMPLOYMENT EXCHANGE, mentioning No. A 5608. L 903

Wanted, Several Good Mechanical DRAUGHTSMEN, preference given to men with workshop training and accustomed to design tools, jigs and gauges.—Apply to nearest EMPLOYMENT EXCHANGE, quoting this paper and No. A 5567, also stating age, qualifications and experience. Good wages. Week of 62 hours (approx.). No person already employed on Government work need apply. L 902

Experienced Aero Engine DRAUGHTSMEN, of designing ability, REQUIRED by a North Midland Aero Factory. Good position and salaries to suitable applicants. No person already on Government work will be engaged.—Apply your nearest EMPLOYMENT EXCHANGE, mentioning No. A 5465. L 730

Wanted, Tool Draughtsman for Aircraft Factory, North-West district. Those with experience heavy press tool work or Cleveland and Acme automatic layouts preferred. No person resident more than 10 miles away or on Government work need apply.—State full particulars of experience, age, and salary expected, to BOX M., care of W. H. SMITH & SON, 55, Fetter Lane, E.C. 4. L 900

Draughtsmen, Mechanical.— Several DRAUGHTSMEN are REQUIRED by a large aeroplane establishment in S.W. London. Applicants should be first-class men, preferably with some shop experience. No one already employed on Government work, or resident more than 10 miles away, will be engaged.—Address, L 938, Offices of ENGINEERING.

Electrical Draughtsman REQUIRED immediately for diagram, layout, and record work, by controlled establishment with large H.T. and L.T. 3-phase A.C. system. Good wages and prospects for suitable man to qualify for permanent post as Assistant Engineer. No one already on Government work will be engaged.—Apply at your nearest EMPLOYMENT EXCHANGE, mentioning No. A 5450. L 757

Draughtsman (Mechanical Engineer), WANTED, on Tyneside, accustomed to general industrial building construction and lay-out of machinery and plant. No person already on Government work will be engaged.—Apply, stating age, experience, and salary expected, to your nearest EMPLOYMENT EXCHANGE, mentioning No. A 5474. L 738

Draughtsman Required, with good experience in design of Steelworks Machinery preferred, although applications from high-class men with other experience would be considered. No one already on Government work will be engaged.—State age, experience and salary required and when at liberty, to your nearest EMPLOYMENT EXCHANGE, quoting No. A 4894. K 868

Leading Draughtsman Wanted Manchester District. Government Contracts. Thorough experience furnace work essential, experience structural work an advantage.—Address, stating age, experience, and salary required, L 873, Offices of ENGINEERING.

Draughtsman Required Im- mediately, thoroughly experienced in Semi-Diesel Oil Engines, land and marine. Good salary will be paid to suitable man. No person already on Government work will be engaged.—Apply, stating age, experience, and salary required, to your nearest EMPLOYMENT EXCHANGE, quoting No. A 5200. L 806

Draughtsmen, Mechanical.— Several first-class Draughtsmen REQUIRED, for the Design Dept. of a large Aircraft establishment in West of England. Applicants preferred with practical experience, not necessarily on aircraft.—Application to be made to your nearest EMPLOYMENT EXCHANGE, stating salary required and mentioning No. A 5534. No person already on Government work need apply. L 811

Draughtsman.—Wanted, immediately, a first-class Engineer-Draughtsman, thoroughly acquainted with general Marine Engineering work. No one already on Government work will be engaged.—Apply, stating age, experience and salary required, to your nearest EMPLOYMENT EXCHANGE, mentioning this Journal and L 880.

Draughtsmen Required for temporary service in an Admiralty Department, a knowledge of Marine Engineering being essential. Salary up to £6 a week, inclusive of war bonus with overtime in addition, according to qualifications.—Applicants to state age and details of experience, to reach BOX No. 1676, WILLINGS, 125, Strand, London, W.C. 2, not later than July 31st. L 877

Draughtsman Required by controlled firm of aircraft manufacturers with works about 25 miles north of London. Applicants should have theoretical and practical training and experience in taking out quantities and making up schedules. No person already on Government work will be engaged.—Apply, stating age, experience and salary required, to your nearest EMPLOYMENT EXCHANGE, mentioning No. A 5501. L 923

Wanted, Experienced and capable Jig and Tool DRAUGHTSMAN, preferably with experience of Motor Vehicle Manufacture. London district. No person already on Government work will be engaged.—Apply, stating age, salary and full particulars of experience, to your nearest EMPLOYMENT EXCHANGE, mentioning No. A 3939. L 803

Draughtsmen Wanted for Shipbuilding and Engineering works in Shanghai.

ONE SHIP'S DRAUGHTSMAN;
ONE ENGINE DRAUGHTSMAN.

State age and salary wanted, with full particulars of experience and copies of testimonials.

No person already on Government work will be engaged.—Apply your nearest EMPLOYMENT EXCHANGE, mentioning No. A 5477. L 915

Draughtsman, Mechanical, WANTED for designing elevators and conveyors. Salary £4 to £5 per week. No one on Government work or resident more than 10 miles away need apply.—Write, "A.D.," care of J. W. VICKERS & Co., Ltd., 5, Nicholas Lane, E.C. 4. L 953

Draughtsmen Required in important munition works. Those accustomed to furnace design preferred. No one on Government work or living more than 10 miles away will be engaged. State experience, age and salary required.—Apply to BOX 134, Advertising Offices, 84, Queen Victoria Street, London, E.C. 4. L 934

Tracers Required in Important munition works. Must have had previous experience. No one on Government work or living more than 10 miles away will be engaged. State age and salary required.—Apply to BOX No. 135, Advertising Offices, 84, Queen Victoria Street, London, E.C. 4. L 935

Draughtsman Required, ac- customed to the Design of Centrifugal Pumps, and preferably with knowledge of Electrical Machinery. Good progressive situation for the right man. No one engaged on Government work or residing more than 10 miles away need apply.—State age, training, and experience and salary required, to your nearest EMPLOYMENT EXCHANGE, mentioning this Journal and L 443.

Good Draughtsmen Wanted, experienced in Power Station details.—Apply, stating age, experience, salary required, and when available, to PREECE, CARDEW, SNELL and RIDER, 8, Queen Anne's Gate, Westminster, S.W. 1. L 909

Wanted Immediately, for Midland firm engaged on Aero Engine work, Jig and Tool DRAUGHTSMAN as Checker. Good salary and prospect for suitable man. No person already on Government work will be engaged.—Apply to your nearest EMPLOYMENT EXCHANGE, mentioning No. A 5426. L 668

Draughtsman Required, with experience in Marine Boiler work.—Address, stating experience, age and salary required, to L 936, Offices of ENGINEERING.

Draughtsmen.—A Controlled Establishment in the West Riding of Yorkshire, engaged on important high priority work, REQUIRE the SERVICES of a competent MAN, with first-class experience in General Engineering work; also experienced MAN for medium size machine tool work. No person already on Government work will be engaged.—Apply, stating full particulars, to your nearest EMPLOYMENT EXCHANGE, mentioning A 4965. L 646

A Lady Tracer is also REQUIRED. The above positions are permanent to reliable individuals. No person already on Government work will be engaged.—Apply, stating full particulars, to your nearest EMPLOYMENT EXCHANGE, mentioning A 4965. L 646

Draughtsman Wanted with experience in Motor Vehicle Design, Commercial vehicle experience desired but not essential. Good salary and prospects for man with initiative and right experience. No person already on Government work will be engaged.—Apply your nearest EMPLOYMENT EXCHANGE, quoting reference No. A 5469. L 747

Draughtsman Required to TAKE CHARGE of Coal Washery Department. Experienced men only need apply.—Full particulars in the first place to K 624, Offices of ENGINEERING.

Crane Draughtsmen.—Leading and Junior Draughtsmen REQUIRED for London district, having either good experience in Steelwork Machinery, Shipbuilding Berth Equipment or General Crane work, although applications from high-class men with other experience would be considered. Permanency for reliable, capable men.

No person employed on Government work will be engaged.—State fully experience, training, age and salary, to your nearest EMPLOYMENT EXCHANGE, mentioning this paper and L 771.

Applications are Invited for the POSITION of JUNIOR DRAUGHTSMAN on the Engineering Staff of a large manufacturing firm in a country district near Bath. Good general experience required.—Address, in the first instance, stating full details of experience and salary required to L 876, Offices of ENGINEERING.

Assistant Draughtsman REQUIRED for Automobile Factory (London, N.W. District), at present engaged on aeroplane work. One accustomed to petrol engine designing. No one already on Government work or resident more than 10 miles away will be engaged.—State age, experience, and salary required, to BOX 9836, care of A. J. WILSON & Co., LTD., 154, Clerkenwell Road, London, E.C. 1. L 916

Wanted, by Firm on South Coast engaged on munitions work, TWO JUNIOR DRAUGHTSMEN, one of whom should be used to Jig and Tool work. Good wages plus war bonus. Shop experience and theoretical training are essential. The posts would be permanent ones.—Applications, stating age and experience, should be made at your nearest EMPLOYMENT EXCHANGE, mentioning No. A 5532. L 907

Aeroplane Erectors Wanted, with good experience; also Engine FITTERS, with Aeroplane or Motor experience on engine fitting, required for large factory near Liverpool. Also several men for laying out operations and materials. Must have machine shop and drawing office experience. No person already on Government work will be engaged.—Apply, your nearest EMPLOYMENT EXCHANGE, mentioning No. A 5427. L 883

Foremen Wanted for Ship- building and Engineering Works in Shanghai. Three Engineering SHOP FOREMEN (with erecting shop experience).

Six SHIPBUILDERS.

Two CARPENTERS experienced in leftwork and pairing.

One MOULDER.

One BOILERMAKER.

Applicants must have held similar positions. State age and wages wanted with full particulars of experience and copies of testimonials.

No person already on Government work will be engaged.

Apply your nearest EMPLOYMENT EXCHANGE, mentioning No. A 5516. L 914

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LITERATURE.

Wood and other Organic Structural Materials. By CHARLES HENRY SNOW, C.E., Sc.D., Dean of the School of Applied Science, New York University. Illustrated. London: Hill Publishing Company, Limited. 1917. [Price 21s. net.]

THE appearance of this book is certainly timely, for the country has lately been invited to consider a large and comprehensive scheme of national afforestation, and some of the questions that agitate the public mind find an answer here. Moreover, so many beneficial results have been foreshadowed as the consequence of adopting the plan submitted by the Forestry Committee, that it may be well if practical experience and ripened judgment remind us of the inevitable losses and drawbacks that figure on the other side of the ledger. We have been alarmed by the disappearance of our woods and forests, and conscious of the risk that has been unwisely accepted in the past, we may be too eager to put into operation every means that promises to augment our timber harvest.

In the presence of a threatened famine, the difficulties attending the afforestation of huge areas with insufficient and untrained labour, are apt to be little considered under the influence of a compelling necessity. The prospect of affording increased employment on the land is regarded as an additional inducement—a welcome by-product that justifies an ambitious scheme. If any one ventures to hint that hitherto our forests have not been a success, either financially, or in the production of structural materials, his cautions meet with no more favour than do the utterances of a pacifist. Dr. Snow, speaking with the authority and with the calmness that knowledge supplies, exhibits no rash enthusiasm for afforestation projects. He intimates that under economical management existing forests may be made more productive, and that if reckless waste could be prevented, both in the woods while growing and in the subsequent treatment of the timber in industry, the world's requirements could be satisfactorily met. At his hands preservation receives as much attention as the production of timber. It is scarcely necessary to point out that the effect of the exercise of thrift and care would be immediate; the benefit of increased acreage is very remote. Naturally, the author's survey is wider than that of our advisers. The need is at our doors and pressing. During 1915–16 alone, it is stated we paid 37,000,000*l.* more than its pre-war value for the timber imported in those years. That is an argument that the Reconstruction Committee can press home with immense effect. Faced with such enormous figures, the time factor, which is equally of the essence of the problem, does not receive its due weight. The same authorities state that we must wait fifteen years before the quicker-growing trees could begin to produce pit props, and not till the lapse of forty years would "the plantations contain enough timber to keep our pits supplied in emergency for two years at the present rate of consumption."

In a subject of such supreme importance and also of extraordinary difficulty, the present rate of consumption must prove a treacherous guide. The consumption of wood goes on ever increasing, notwithstanding that iron and stone and concrete have replaced it to a considerable extent in many structures. Whatever relative decrease these substitutes have wrought, the absolute increase remains unaffected. More wood is used than ever before in our history. It may, however, be argued that a scarcity of wood and of other organic substances used in construction is less to be feared than that of the inorganic materials derived from our mines and quarries, since wood is capable of reproduction. Minerals existing in fixed and limited quantities, the more such substances are exploited, the nearer is the day of their final exhaustion approached, without any possibility of restoring the extracted wealth. This argument, or expectation, however, contains a fallacy. The possible annual increment of wood is strictly limited, and as soon as consumption outstrips this amount, we are drawing on our reserves as certainly as in the case of mineral extraction. We have no exact information as to the annual weight of timber added to our trees by physiological processes, but as the number of trees diminishes, so does the total amount of the annual deposit. When Dr. Snow tells us of trees whose magnificent proportions have resulted from the accumulations of more than 2,000 years, it is hard to believe that we have not drawn upon the accretions of past ages.

Some comfort may be derived from the reflection, that forestry teaches a method of maintaining the forest in such a condition that it remains unimpaired and productive for an indefinite time, but if we have not applied those processes that science indicates and whose efficiency is admitted, the greater is our condemnation. We may flatter ourselves with the knowledge that the natural death of a tree is unknown and improbable, but to think that the power of reproduction will save us from the effects of extravagance and waste is to encourage a delusion. The necessity for heroic measures to remove the consequences of past neglect is shown by the scale on which the Forestry Committee have made their recommendations, and affords sufficient evidence of the thoroughness of the depletion of growing timber in this country. The enormous forests of America are showing signs of the unrestrained havoc of the lumberman, who disregarding the principles of scientific preservation, is rapidly exhausting the natural accumulations of centuries. The white pine, that till recently supplied 30 per cent. of all the lumber used in the States, is growing scarce, and in some districts has disappeared before the devouring axe of its most ruthless enemy, the lumberman. No other wood known to man has been so valuable, no perfect substitute for it has been found: we cannot but regard its growing scarcity with dismay. Other instances might easily be found, where greed has outrun prudence, and future generations will be the poorer, because insufficient steps have been taken to secure recurring crops of those trees that are most valued in construction and industry.

Although a note of caution or regret over irreplaceable waste may be detected at times, the main purpose of the author is to assist engineers and students by discussing the more important physical characteristics exhibited by those materials of organic origin that are used in construction. Hence though timber; its varying properties depending on growth, its strength and fitness for constructive works; its protection against attacks by fungus and insects; its destruction by fire and the adoption of preventive measures against such loss, is the main topic of discussion, other organic substances that claim the attention of the engineer or architect come under review. These include paint and varnishes, their associated oils, gums and resins; glues, and even indiarubber receives a short notice. The separation along the lines of organic and inorganic materials may seem a little fanciful, but one main object of the author is to direct attention to the method of official testing, and the modifications that the structure of organic materials demands. In Dr. Snow's opinion, strength of material is too much insisted upon as the one thing needful, and the meaning of the term as well as the inevitable variations in the material itself are too little recognised. The importance attached to this quality of strength may be a consequence, or an imitation, of the tests usually applied to inorganic materials, which are characterised by greater simplicity of structure, homogeneity and constancy. The results of physiological processes and the influence of life manifestly introduce variations that cannot be detected by tests as ordinarily conducted: the several parts of the same tree often exhibit such wide variations that the decisions of purely mechanical inquiry become fallacious. The selection of representative specimens is a matter of difficulty "Most large pieces are individual rather than representative, and tests on such pieces yield results for the pieces thus broken, rather than results that represent the species at large." The cellular structure of the wood, the arrangement and character of the cell elements, the amount of moisture and the characteristics of compounds associated with cell structure, all contribute in their degree to give to the wood the properties that are valued. The definite determination of hardness, elasticity, weight, density, porosity, and other qualities, the modification of each property by age and other variables present special difficulties, but to judge of the mechanical usefulness of a specimen, it is necessary to know the tendency to split, the ability to hold fastenings, and other qualities which hardly admit of mechanical tests. Hence knowledge, intelligence and observation are required to supplement the mechanical process, and the author attempts to direct judgment, or at least to give reasons for decisions on critical points. The correct identification of the tree, the study of its formation, the injury the wood may receive while growing, and, in fact, the natural history of the tree, are all elements to be noted in determining the usefulness and suitability of its timber. Genus, species and families may not be overlooked, and several chapters are well devoted to a description of the different trees grown, and the timber used, in the United States, detailing the most characteristic properties.

In these chapters it is possible to trace the effect of life processes in building up the timber product. But life also implies decline and deterioration, due to exposure, age, decay and other wasting influences. Fungus growth and insect ravages exact a heavy toll, while forest fires and the destruction of buildings explain the disappearance of large quantities of timber. Care and special treatment reduce these losses somewhat, and to insist on the adoption of appropriate protective and preservative measures is the main object of the second half of the treatise. Fungus disease operates in many ways, but neither live trees, nor trees in which life processes have ceased, nor wood prepared for structural purposes, are immune from attack. The number of species is enormous and the method of attack almost as varied. Some kinds of growth prefer conifers, and others the broad-leaved trees, but bark, heartwood and sapwood all have their special enemies: foliage, roots and trunk may each be the seat of attack when the conditions are favourable for fungoid development. The health of the tree is the one important factor in stopping or reducing the virulence of the assult, for when health is lowered the power of resistance is lessened. The subject is a very large one belonging to the domain of mycology—it is treated here in some detail, and rightly, as the consequences of fungus growth may be visible in merchantable timber and come under the notice of the engineer.

If by good health, or good luck, our tree escapes the enemy of fungus, various forms of animal life lie in wait to deliver a deadly assault. Not only in the growing tree, but on timber worked up in construction, many species find a comfortable home, and invariably destroy the material that shelters them. The hulls of wooden ships are penetrated by marine borers, but they must find their operations limited by the more general use of iron and steel. In days gone by, the ravages of these pests were so great as to compel owners to discriminate against harbours where they were known to congregate. On land, the destructive work of the termite is well-known. Live trees fall victims, but the termite, generally preferring tissues in which life processes are exhausted, looks to timber and furniture to provide him with ample field for mischief. Many preservatives have been recommended, but Dr. Snow is persuaded that the use of creosote is the only one that is worth considering. As long as creosote lasts the timber is protected, and creosoted piles have been known to last forty years. A more complete protection is found by substituting metal for wood, and herein lies perhaps the only complete remedy, for it seems probable that insects will always remain with us, for man with every inducement to rid himself of destructive ants and beetles, has not yet succeeded in eliminating a single species. But man is the most cunning of all animals, and his ingenuity is not exhausted: some insects prey on others, and by enlisting the services of the helpful members he may succeed in reducing the harmful to innocuity. Unfortunately, if the insects who contribute to this happy result find their means of livelihood diminished, they may change their manner of life in such a fashion as to make the last state worse than the first.

The seasoning of wood and the processes of preservation, whether by internal or external treatment do not permit of the introduction of much

novelty, but the details are well described, and cover the ground. The subject in its many aspects is one of increasing interest, for owing to the advance in the price of wood, the prospect of efficient preservation grows attractive. The author points out that while prior to 1901, only 15 timber-preserving plants were in operation, the number increased to 50 in the six following years. The desire to secure immunity is shown by the patent statistics, which record that nearly 500 substances and processes have been suggested, and the difficulties in the way of attainment are equally demonstrated by the fact, that the American Society of Civil Engineers, considered only four of them as deserving a full report. In spite of the 30 years elapsed since that report was rendered, the number of trustworthy processes can hardly be said to have increased.

Conflagrations and protection against fire seem to be rather remote from the main enquiry, but it must be remembered that America suffers severely from accidental fires. Wood being plentiful in the States, has been very largely used as a constructive material, especially to meet the first needs of the settlers, and this inflammable material is responsible for much of the loss. Nevertheless, it comes as a shock to read that while in six European leading countries the annual loss, *per capita*, is only 30 cents, in the United States the tax is more than eight times as great. The direct fire loss in 1910, the latest year given, considerably exceeded 200,000,000 dols. In further explanation of this loss, the author points out, that European policy has been directed to the prevention of fires, but that the Americans have concentrated their attention on improving the means of extinguishing them. The details given here are very minute, and imply a caution which shows that the American mind is quite aware of the gravity of the situation.

In the final chapters, the organic ingredients found in paints and varnishes, as well as of glues and adhesives are considered. The subject is too large for adequate treatment, and the author's attempt may be considered as rather too ambitious. His programme includes the materials of which paints and varnishes are composed: the methods used to apply these protective compounds, with the influence such methods exercise on durability, together with the preparation of woods to receive paints and varnishes. The operations of many trades come under review here and the details are rather crowded. But it is well to be reminded of the manner in which the organic world contributes to the work of construction, how manifold and various are the operations needed, and the extent to which organisation must be carried to admit of all being ordered with harmony and economy.

Water Supply, Considered principally from a Sanitary Standpoint, 1916. By WILLIAM P. MASON, Professor of Chemistry, Rensselaer Polytechnic Institute. Fourth edition. New York: John Wiley and Sons, Inc.; London: Chapman and Hall, Limited. [Price 17*s.* 6*d.* net.]

THE merits of this treatise have been fully acknowledged both in England and in America. Twenty years have elapsed since the first edition appeared, and the favourable opinion then formed has been strengthened by time and examination. By the addition of new material to the successive editions, the information has been kept up to date—no easy task—but the author has maintained so sure a grip on the accumulating mass of literature, by which many writers have enriched the subject, that he is able to present in a lucid and concise manner the results of the principal investigations, bearing on the sanitary aspects of water supply. He deals with a subject that has a far reaching interest for the sanitary and social reformer, and one whose importance is very generally admitted, but the accurate information that would qualify many of this class to assist in promoting improvements, or would suggest intelligent criticism of the manner in which municipal authorities fulfil their obligations is by no means so widely distributed as it should be. Such a book is needed to instruct the increasing army engaged in water collection and water distribution concerning the many matters that fall within their province. For progressive legislation has placed on landowners, local sanitary boards, and other bodies, new duties and additional responsibilities for whose discharge they are insufficiently equipped by their existing knowledge and experience. But whoever appeals to this volume for assistance and enlightenment, whether layman or professional, will hardly go away disappointed.

The public is usually satisfied with the water, when the appearance is attractive and no pronounced taste or smell is perceptible, only at moments of excitement or alarm insisting on proper precautions being taken to ensure freedom from the presence of toxic or harmful properties. For all glaring defects the expert adviser is held responsible by the public on the one hand and the water committee on the other, but the author intimates that a new terror is approaching our Water Boards, and that in the near future there is a prospect of legal action being taken to secure damages for the distribution of unsafe water. He is able to quote a case heard in the Supreme Court of New Jersey, in April, 1915 in which damages were awarded to a plaintiff who sued the local Water Company for expenses and loss of time arising from the illness of his children, who contracted typhoid fever from the impure water supply. We are not called upon to decide whether action would lie under similar conditions in England, but the American Court held, that as the defendant company was in the water supply business for profit, they might be regarded in the same light as a dealer in food stuffs. The company was, therefore, bound to supply the plaintiff with water "ordinarily and reasonably pure and wholesome."

This phrase raises the question of what is a "good, pure, wholesome water," adjectives that to the layman at least seem free from ambiguity and express the obligation he would impose on every water company. The words, however, are sadly wanting in definiteness, and it is not easy to frame a definition that would be free from objection. The author analyses each of these attributes and demonstrates its ineptitude or insufficiency. A water impregnated with calcium sulphate may be, and is, very *good* for the brewing of light ales, as the reputation of Burton-on-Trent amply attests, but very bad for boilers or laundry use. Pure water, chemically pure water, is very difficult to prepare, and harder still to preserve; such clearly is not the water contemplated by the definition, and if a certain amount of impurity, organic or inorganic is allowed to be introduced, little progress is made, for the quantity or quality of either is left indeterminate. Wholesome, in the sense of tending to promote health, is equally vague, for potable water may be quite wholesome to those who are so acclimatized as to be tolerant to its use, but injurious to new comers or those inclined to certain constitutional disorders. Professor Mason would substitute "safe and suitable" as more appropriate words, but at the hands of an expert cross-examining counsel, he would probably find himself on equally unstable ground. As a matter of fact his whole book is a reply to the question what is a suitable potable water and how is its suitablity to be maintained?

In determining the suitability of potable water, the public are apt to appeal to tests that are crude and unessential. Transparency, odour, and relative hardness are the features that usually carry the greatest weight, though little importance should be attached to these qualities. Water may be deeply coloured and yet perfectly wholesome. If this colour, as is often the case, be due to impregnation with peaty material, very beneficial results may follow its use, though the mode of operation is obscure. In parts of South America, the water preferred for drinking is coffee brown or greenish black. The amount of material carried by these and other better known waters is so great, that decomposition might be feared, nevertheless they "keep well," the nitrogenous matter remaining permanent for months without developing free ammonia or other indications of decay. Filtering plant is the usual remedy to correct any unsightliness, for the public demands a clear and sparkling water as a token of purity. Objectionable odours usually arise from the death and decay of minute organisms and algæ growths. This annoyance may offend the æsthetic sense, but no proof has been furnished that the presence of such growths is provocative of disease. Living microscopic organisms can produce compounds of the nature of essential oils, of course, minute in quantity, but so delicate is the sense of smell, that the presence of one part of oil in two million parts of water can be detected. Such homœopathic doses threaten no disturbance to the system. The copper sulphate usually employed to remove algæ growths, in the proportion of one part to three million parts of water, can be quite as deleterious as the objectionable matter destroyed. The author calls attention to a novel plan of double sand filtration and double aeration that is very successful in overcoming offensive tastes and odours, and at the same time reducing in a very substantial degree the iron, organic matter and colour of the water treated. The quality of hardness due to the presence of certain minerals in the water is noticeable in greater or less degree in every public supply, but though complaints are raised when the hardness exceeds a recognised standard, there is little reason to credit the sensational statements sometimes made. All the evidence points to the conclusion that the rate of mortality is practically uninfluenced by the softness or hardness of the water. The Kentish water, drawn from artesian wells, has an unenviable reputation for hardness, but medical authorities state that though the hardness is an intolerable nuisance, it is in no way injurious to health or the cause of gouty ailments as popularly supposed.

The care taken to ensure the production and distribution of wholesome potable water is both satisfactory and successful. Municipal authorities are not only desirous that the public supply should be above suspicion, but experience has taught how to secure sterility and freedom from pollution. Advantage is everywhere taken of the processes that operate in favour of natural protection, as that of sedimentation for example, and such constant effort is made to supplement and increase these aids by special devices, such as filtration, the use of ozone or the treatment by ultra violet light, that the typhoid bacillus and other pathogenic germs have little opportunity to spread. The ingenuity and resource exhibited in fighting water-borne disease deserve very full acknowledgment. As soon as science suggests the possibility of increasing the safeguards that give protection to public health, a scheme is worked out to make those suggestions practically operative. Even the possibility of making distilled water available for dietetic purposes has been canvassed: the efficiency of the method excels that of all other processes, so unfortunately does the expense.

With the existing precautions against contamination and infection, it may be questioned whether there is any need for household filtration, and where carried on, what is its practical value as a sanitary measure. The author without hesitation declares that filtration to be effective must be municipal and this verdict will be accepted by experts. One reason for this decision and one that is not appreciated at its proper worth by the ordinary householder is the comparative efficient protection secured by breaking up the concentrated masses of pathogenic bacteria. The action of filtering plant on a large scale is to separate the collections of disease germs, rendering those that pass the filter comparatively harmless, owing to their distribution throughout a larger volume of water. In this attenuated condition the germs fail to break down the natural defences against disease. An army acting in mass is far more effective than the same number of scattered units. The householder who relies on his own care and knowledge trusts to a weak reed, for where examination has been thorough and exhaustive very unsatisfactory results have been disclosed. The Pasteur filter has many advocates and deservedly, for undoubtedly water can be completely sterilised by filtration through unglazed porcelain. The length of time, however, during which a sterile filtrate will be furnished is very limited. The "Pasteur" will remain effective only, if the "Candle" and its rubber packing are removed once a week, thoroughly washed and then boiled half an hour before being reset in position, the latter process requiring rather nice handling. Any filter, however perfect in principle, that requires

this care and attention for household purposes will prove a failure, and moreover if the conditions under which sterilization can be procured were thoroughly explained to the public, the sale would be ridiculously small. Some types of household filters are defective in original construction, and some cannot be cleaned without the entire removal of the filtering material. Professor Mason quotes a case of a sponge filter, that came under his own observation, that furnished a filtrate containing 121,000 bacteria per cubic centimetre as compared with 540 in the same volume of unfiltered water. The charcoal filter in a neglected condition is a pitiable sight and the confidence placed in it pathetic, but it is difficult to find a more objectionable appliance from a sanitary point of view. After a month's use, the number of organisms in the household filtered water will be five time the number in the unfiltered.

That the municipal filtering plant does the work it is intended to perform and is entitled to our confidence as a thoroughly effective process, is shown by the following statistics:—

Average annual typhoid deaths per 100,000 population in seven cities of New York prior to the introduction of slow sand filtration	46.5
Average typhoid death-rate in same cities, 1915	13.3
Similar data for 11 cities prior to mechanical filtration	56.2
Typhoid death-rate in same cities for 1915	14.4

Notwithstanding the increase of population and the consequent greater discharge of sewage and deleterious matters into the streams, the lowered death-rate is very gratifying and shows the competency of water engineers to deal effectively with the increasing danger. The amount of river pollution is excessive and constantly growing, while little attention is paid to the rule once sought to be enforced, that a riparian owner is entitled to receive from the up stream occupier, a stream flow undiminished in quantity and uninjured in quality. Possibly in strict law the same rights hold, but there is noticeable an increasing determination to regard rivers and streams as the natural drains for the country, providing a convenient vehicle for carrying to the sea all waste materials the communities on the banks find it advantageous to despatch by that route. This is no place to enter into the discussion of so mixed a question, but we may express a firm belief that the resources of engineering science will succeed in overcoming the danger that threatens to follow the march of industrial progress. This confidence is materially strengthened by the study of the details of many ingenious schemes that Professor Mason has put forward with equal lucidity and cogency.

A Treatise on the Principles and Practice of Harbour Engineering. By BRYSSON CUNNINGHAM, D.Sc., B.E., M.Inst.C.E. Second Edition, revised and enlarged. London: Griffin and Co., Limited. [Price 25s. net.]

THE appearance of a second edition of this work is a better testimony to the value of the material collected and discussed than any brief summary of its contents could offer. The suggestions of friends and the criticisms of experts must have contributed to enlarge and improve a work which, even in its earlier form, was a valuable addition to our technical literature. Continual advance in construction and more exacting demands for increased facilities to meet the requirements of an ever-growing standard of shipbuilding have necessitated much revision, and the author is to be congratulated on the manner in which he has met these wider conditions.

The subject of harbour engineering in its initial stages is a restricted one in practice, because the opportunities for the construction of new harbours must be few, and the subject matter is confined very closely to problems connected with those external works of defence, that permit the building of docks and wharves to assist the handling of traffic. Repairs and extensions are more frequent, but then the scope for originality is limited by existing works, and the direction development must take is prescribed. And yet, perhaps, there is no class of engineering work in which the designer receives less assistance from the lessons of experience and the guidance of authority. Every case that is approached calls for the exercise of individual judgment, for the number of variables is so great and the hazards to be accepted so numerous, that it is unsafe to rely upon the pronounced similarity of conditions with some previous undertaking.

To the engineer following this branch of his profession the history of every effort at harbour construction, whether successful or unsuccessful, is deserving of careful and detailed study, though in no case may imitation of any specific instance be possible. The nature of the sea bottom, the configuration of the coast, the percussive action of the waves, the behaviour of the tides and currents, the extent of structure exposed, the proposed degree of efficiency, all offer an endless variety of problems that have to be weighed and balanced, before any scheme can be put in execution. Each proposal has to be decided on specially collected data, that are often imperfect in their character and always difficult of interpretation. Even when facts are agreed upon, unanimity of decision is impossible, as was instanced by the action of the members of the Milan Conference on Breakwaters, who limited the expression of their views to declaring "that the information contained in the report was of great value for the construction of breakwaters, especially in regard to the force of waves, but by reason of the great diversity of cases it was not thought desirable to formulate any absolute conclusions."

When authorities can draw conflicting conclusions from similar data, it will be admitted that the general method pursued by Mr. Cunningham in dealing with debateable topics is not only free from objection, but is altogether admirable. In the various problems considered, where there is room for indecision or alternative treatment he lays down the main principles that serve for guidance, and adds detailed references to representative examples of the chief types, that best illustrate the principles enunciated. Although some notable instances in recent harbour construction are not mentioned, and the stern repression of the censor sufficiently explains their omission, the author is not without a goodly number of examples. The classical and instructive story of Madras is told over again for our edification, and the record of disasters and remedial expedients of which Pillau Harbour was the theatre is made to convey a useful lesson to those who undervalue the need of stability of structure.

In order to construct a harbour, it will be necessary to make a survey of the neighbourhood concerned and to plot the submarine contour lines. Boreholes will probably have to be drilled to ascertain the nature of the river or sea bed, its fitness for anchorage, and the measure of stability to be expected. The subsequent plans will be drawn after consideration of the height and force of the waves, the direction and velocity of currents, the amount of silting, of littoral drift or coast erosion. Accordingly in the early chapters, the author describes the methods in use by which these preliminary data are determined. Perhaps all this information can be found elsewhere and even discussed more thoroughly in special technical treatises, but here so much of the processes as are necessary are adequately and conveniently described.

The constructive works, properly so called, may be regarded as divided into two main classes: the one a framework structure in which each component member is superficially small, offering a very trifling obstruction to current flow and consequently causing insignificant disturbance to the coastal regime; the other a compact solid mass whose ideal form would be a homogeneous monolith, without break or joint, capable by its own inertia of withstanding the severest attacks of the elements. Under the former class is described the work of "piling," the preparation of a support, on which trussing, bridgework, &c., can be carried. The materials used in piling, whether timber, metal, or reinforced concrete, are considered with some minuteness, and the destructive work of animal organisms on timber of various kinds is graphically exhibited. The author adds his testimony to the growing conviction, that the only effective timber preservative against insect attack is creosote, but with this precaution invulnerability cannot be guaranteed. When a solid mass of rubble or masonry is the form decided upon for the construction of a breakwater or mole, ready access to suitable stone is of prime importance, and this consideration gives opportunity for a chapter on quarrying, the choice of stone of suitable size, and the transport of material. This topic may seem rather remote from the main lines of the treatise, but the record of personal experience is always useful and to some the information may be new and valuable.

Problems in breakwater design and construction forming, as these do, the most prominent and fundamental features in connection with artificially sheltered harbours claim two important chapters. Engineers probably have fairly accurate notions of the intensity of the external forces against which it is necessary to contend and of the potent character of wave agency, but outside that comparatively small coterie, the destructive force to which submarine structures are submitted is little appreciated. This want of exactness is due in a great measure to the need of trustworthy appliances for registering directly the compressive force of the wave stroke over a large area. But apart from the evident consequences, and the author's comments and illustrations are most effective and convincing, there still remain subsidiary effects whose grave consequences may be overlooked till they are submitted to actual calculation. Among these are to be reckoned air compression and water hammer. The former of these may give rise to stresses more than three times as great as the external pressure, and when the conditions favourable to water hammer are allied with high velocity of impact, the internal pressure may amount to 15 times that on the face. Such theoretical considerations emphasise the difficulty of construction and enforce the necessity for a large factor of safety after all possible precautions have been taken.

Evidently as the harbour works approach land, the province of the harbour engineer tends to coalesce with that of the dock engineer and the naval architect. Pierheads, quays and landing stages form the common ground on which the several classes of specialists meet. The pierhead is itself a solid and oftentimes a practically independent structure, that may be regarded as the keystone of a breakwater's stability, but its equipment for port facilities has little to do with harbour construction. Similarly, landing stages are concerned with the general traffic, and convenience becomes a controlling factor in their arrangement and construction. They may, owing to environment, be either fixed or floating, but in the latter case the features and characteristics peculiar to buoyant structures present themselves. The treatment of the behaviour of floating bodies is elementary, but adequate, for the subject may here be regarded as a detail not directly bearing upon harbour construction.

Two important chapters are given in conclusion on "Entrance Channels" and "Channel Demarcation" respectively. The regulation and maintenance of efficient approaches to ports are of extreme moment, only to be appreciated by those who have had experience of the difficulty of keeping an uninterrupted fairway. Fluctuations in depth due to drifting sand and detritus, inaccuracies in tidal information, variations in coast line brought about by erosion, and in cases where the port is on an estuary, alterations in the direction of the river current, are continual sources of anxiety and expense to the port authorities. To have much practical information and advice brought together in a convenient compass, and critically discussed, cannot but be appreciated by those responsible for the maintenance of our ports. The provision of efficient guidance through these varying and often tortuous channels, by means of buoys and lights, through entailing no great engineering difficulties, raise many interesting problems, which find a fitting elucidation in these chapters.

There is, however, another set of problems of wide national importance to which we can make only the briefest reference. Should the State be held responsible, for the upkeep of its ports, the development of its harbours, and the care of its estuaries? The nation, generally, and not merely local enterprise, is concerned in the economic value of the

waters, and on that ground there is apparently a claim on the Imperial Exchequer. The question, of course, is very complex, and its decision must be left to private judgment or the ingenuity of local debating societies. Expediency rather than legality will generally furnish grounds for decision. The right to enclose a basin and to construct docks may prove a valuable gift to a privileged community: to compel a few struggling fishermen to provide a refuge from wind and waves in order to carry on their precarious craft may be to inflict an intolerable burden. Ports that are seen to be prosperous may claim to retain their independence and to work out their own programmes of development, but are ports that appear to be growing obsolete to be assisted from the public exchequer? The extinction of a centre of commercial activity, brought about possibly by natural causes of erosion, the results of legitimate enterprise on another part of the coast, can hardly be regarded with indifference, and in many cases the public funds have given aid to local endeavours. The policy of partial assistance seems to be increasing: it is one that recommends itself on the ground of compromise and expediency.

Elements of Industrial Chemistry. By ALLEN ROGERS. London: Constable and Co., Limited. [Price 12*s.* 6*d.* net.]

THE title page of this octavo volume of 512 pages styles the book an "Abridgment of the Manual of Industrial Chemistry," written by Forty Eminent Specialists and Edited by Allen Rogers. None of these specialists are mentioned, nor is the name of the co-editor of the Industrial Chemistry of 1912, Professor Alfred B. Aubert, given in this abridged edition, the preface of which is dated from the Pratt Institute, of Brooklyn, New York, September 20, 1916. It is pointed out, however, that no claim for originality is made for the new volume, and that full credit should be given to the contributors to the earlier, larger book.

When reviewing this first publication in our issue of January 31, 1913, we expressed our inability to decide to what class of readers the editors meant to appeal. A different scale of criticism must, of course, be applied to a volume which has been reduced to half the original size by the excision of whole chapters (of which there are now 27 instead of 43), and of paragraphs. But we are afraid the technical chemist and student will frequently be disappointed when consulting this new edition. On the whole, the subject-matter remains as it was. The 117 illustrations include some new diagrams, *e.g.*, of disintegrating machinery, a few additions have been made in the text, the three lines on ozone, which we characterised as a gem in our previous review, have been replaced by 1½ pages of readable matter, the Linde oxygen process and permutit are presented to the reader, and some novelties are noticed, though there is no claim to this effect. But gone altogether are the bibliography and all the references—which were a very weak feature of the original book—and the chapters on materials of construction, on laundering, water testing, glue and gelatine, and on iron and steel. Instead of the latter we have 6 pages on iron and its compounds, forming part of the chapter of 70 pages on Elements and Inorganic Compounds. This chapter is written in dictionary style, alphabetically arranged; arsenic and boron receive half a page each, neon one line, nickel 15 lines, silicon and water glass 18 lines, and the editor would have done much better if he had cut out this section altogether, and had concentrated more on general processes (disintegrating, sifting, evaporating, furnaces), and what may briefly be termed applied organic chemistry. Some of these chapters, on coal tar, petroleum, oils, essential oils, soap, varnish, paper, &c., are quite acceptable, in spite of their brevity. Authors should understand by this time that industrial chemistry cannot be dealt with in a single volume.

BOOKS RECEIVED.

Department of the Interior, U.S.A.: *Bureau of Mines.* Bulletin 159, Law Serial 12. *Abstracts of Current Decisions on Mines and Mining, Reported from May to August,* 1917. By J. W. THOMPSON. Technical Paper 155. *Mineral Technology. Gypsum Products, their Preparation and Use.* By R. W. STONE. Washington: Government Printing Office.

Liverpool Corporation Tramways: Annual Report of the General Manager for the Year, 1917. Liverpool: H. C. Tinling and Co., Limited.

Annual Report of the Department of City Transit of the City of Philadelphia for the Year ended December 31, 1916. Philadelphia: The City of Philadelphia.

Directory of Paper Makers of the United Kingdom for 1918. London: Marchant Singer and Co., 47, St. Mary Axe, E.C. 3. [Price 2*s.* 6*d.* net, post free in United Kingdom; 2*s.* 8*d.* abroad.]

THE LUBRICATION OF MICHELL BLOCKS.

IN the applications which have hitherto been made of Osborne Reynolds' theory of lubrication, it has been customary to assume that the viscosity of the lubricant does not vary as it passes through the bearing. On this assumption it followed that for efficient lubrication a Michell block must be supported behind its centre of figure in order to secure the necessary fine wedge of oil between the opposing surfaces, and, moreover, such a block, if centrally supported, should have no load-carrying properties whatever. It was found by actual experiment, however, first, we believe, by Kingsbury, and later on by Sir C. A. Parsons, that a centrally-pivoted block could, as a matter of fact, carry quite a high load. In his reply to the discussion on his paper on the Problem of the Thrust Bearing, read before the Institution of Civil Engineers in 1914, Mr. H. T. Newbigin pointed out that this experimental result was due to the fact that in applying Reynolds' theory the variation of the viscosity of the oil as it rose in temperature during its passage through the bearing had been neglected, and that when this factor was taken into account the experimental facts were quite in accord with theory. The effect of this changing viscosity of the oil has been further investigated, both theoretically and experimentally in the laboratories of Messrs. Brown, Boveri and Co., of Baden, Switzerland, and an account of these researches appeared last year in the *Revue B.B.C.*, which is a publication issued by the firm in question. For a block infinitely wide as compared with its length measured in the direction of motion, Osborne Reynolds* gave the equation:

$$\frac{dp}{dx} = -6\lambda\,\frac{h-h^1}{h^3} \quad . \quad . \quad . \quad (1)$$

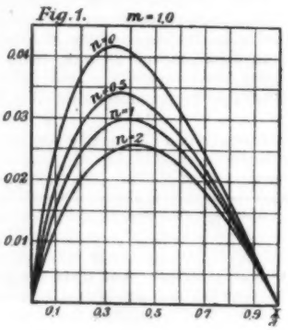
where p denotes the pressure of the oil, x the distance of any point of the block from the origin, and λ the viscosity of the lubricant, whilst h denotes the distance separating the opposing surfaces at any point x, and h^1 is the value of h at the point where the pressure is a maximum.

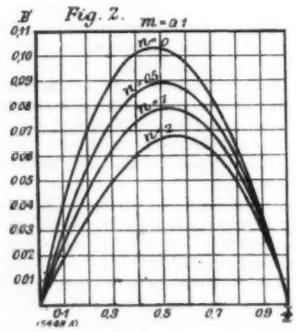
In integrating this equation Osborne Reynolds assumed λ to be constant, although, as is well known, the temperature of the oil may be greatly increased by its passage under the block. In the article in the *Revue B.B.C.* the assumption is made that the viscosity λ may be expressed in the form

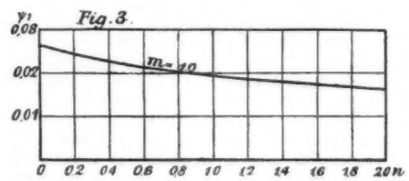
$$\lambda = \lambda_0\left(1 + \frac{n}{a}\,x\right)$$

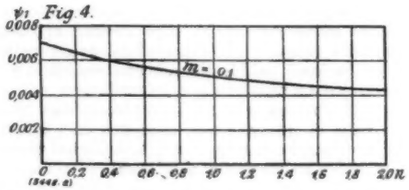
Here λ_0 denotes the viscosity of the oil as it *leaves* the block, whilst a denotes the length of the block and n a coefficient. The viscosity of the oil as it enters the block is therefore $(1 + n)\,\lambda_0$.

With this substitution equation (1) can still be easily integrated, and the results for particular values of the constants involved are given as curves in Figs. 1 and 2, which we reproduce from the *Revue B.B.C.* In these figures m is defined by the relation $h = h_0\left(1 + \frac{m\,x}{a}\right)$, where a, as before, is the length of the block taken in the direction of motion and m measures accordingly the inclination of the block of the other bearing surface. With $m = 1$ the distance between the two surfaces is twice as much at the leading edge of the block as at the trailing edge, and this is approximately the condition for maximum sustaining power. It appears from Fig. 1 that when $n = 0$, that is to say when the viscosity is constant, the maximum pressure and the line of action of the resultant pressure lie distinctly behind the centre of the block. As n increases, which corresponds to the viscosity becomes smaller as the trailing edge is approached the centre of pressure shifts forward, but with the particular value of m for which this figure has been drawn it does not get as far forward as the centre of the block, even when the viscosity at the leading edge is three times as great as at the trailing edge. Fig. 2 corresponds to a much smaller angle between the opposing bearing surfaces, having been drawn for $m = 0.1$, the value of h at the leading edge is thus only 10 per cent. more than at the trailing edge. In this case the change in the viscosity has, it will be seen, a much greater influence on the position of the centre of pressure. This becomes nearly coincident with the centre of the block when the viscosity is only 50 per cent. more at the leading edge than at the trailing edge, whilst with $n = 2$ the centre of pressure is, it will be seen, well forward of the leading edge. The two curves show pretty clearly that to carry a given load the oil film will be thinner with a centrally-pivoted block than with one which is pivoted behind the centre line. This thinner film will be subject to a more severe shearing action, and the development of heat should be greater than with the centre of pressure behind the centre of figure. This conclusion is borne out by the experiments quoted by Mr. H. T. Newbigin in the discussion on Mr. Stoney's paper, read before the North-East Coast Institution of Engineers and Shipbuilders in 1914. In these experiments a block was run under constant load, but with different positions of the pivoting point, the results were as follow:—







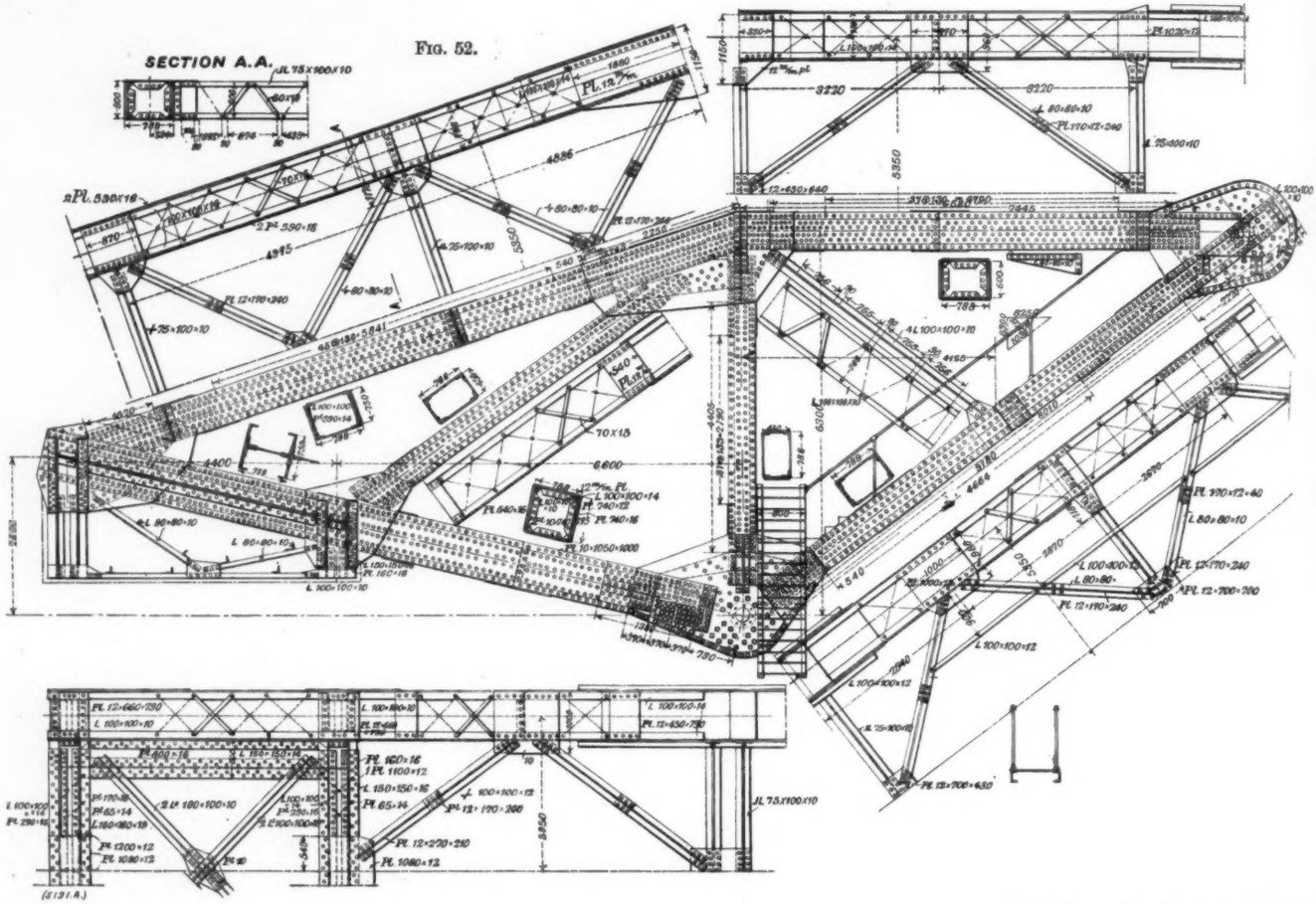


* For a detailed exposition of Reynolds' theory, see ENGINEERING, July to December, 1915, pp. 101, 154, 196, and 207.

BASCULE BRIDGE OVER THE TROLLH

(For Description, see Pag

FIG. 52.



FIGS. 52 AND 53. DETAILS OF BALANCE LEVER.

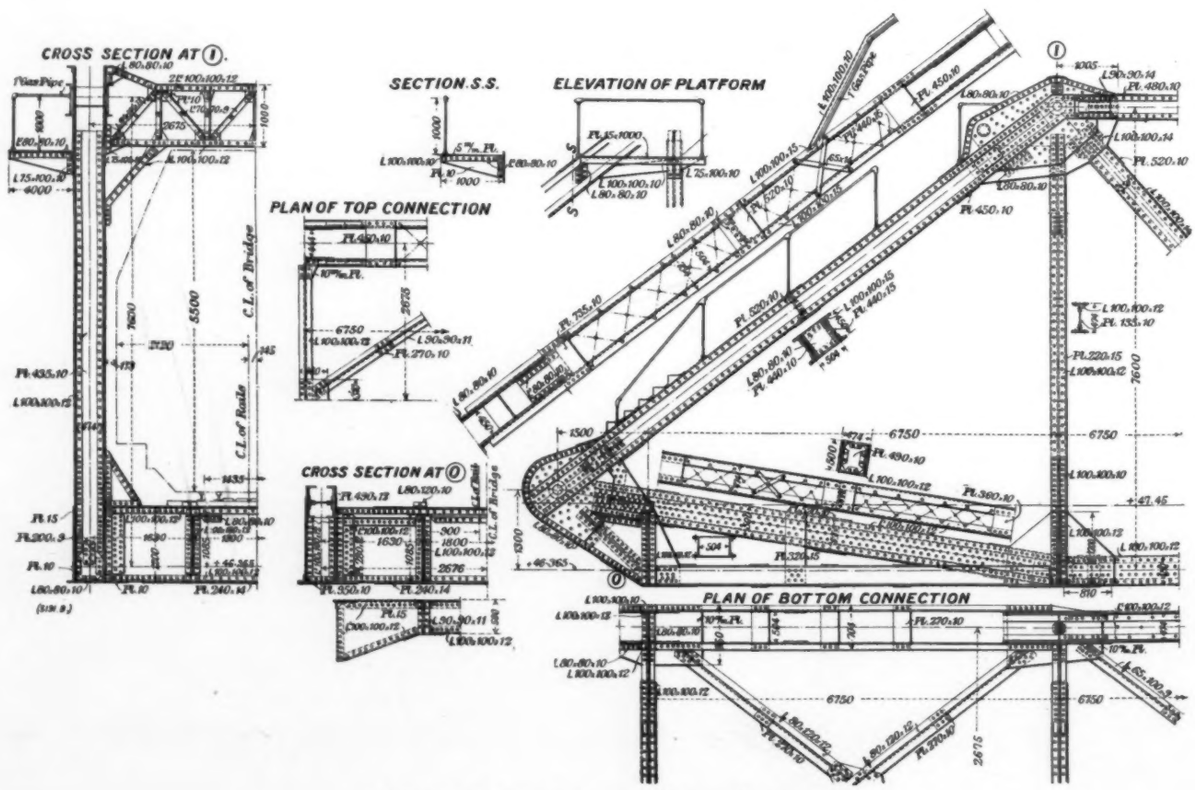


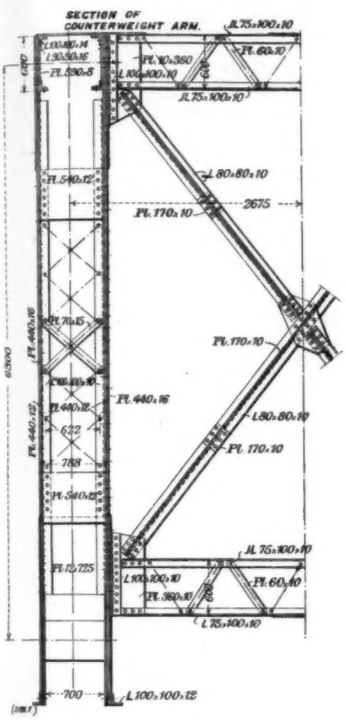
FIG. 55. DETAILS OF PANEL AT HINGED END OF SPAN.

FIG. 56. CROSS SECTIO
SPAN.

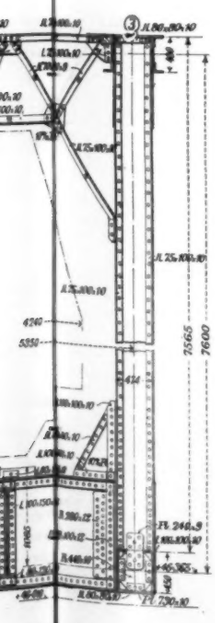
TROLLHÄTTA CANAL AT VANERSBORG.

(Description, see Page 715).

FIG. 53.



ANCE LIFT.



3. CROSS SECTION OF LIFTING SPAN.

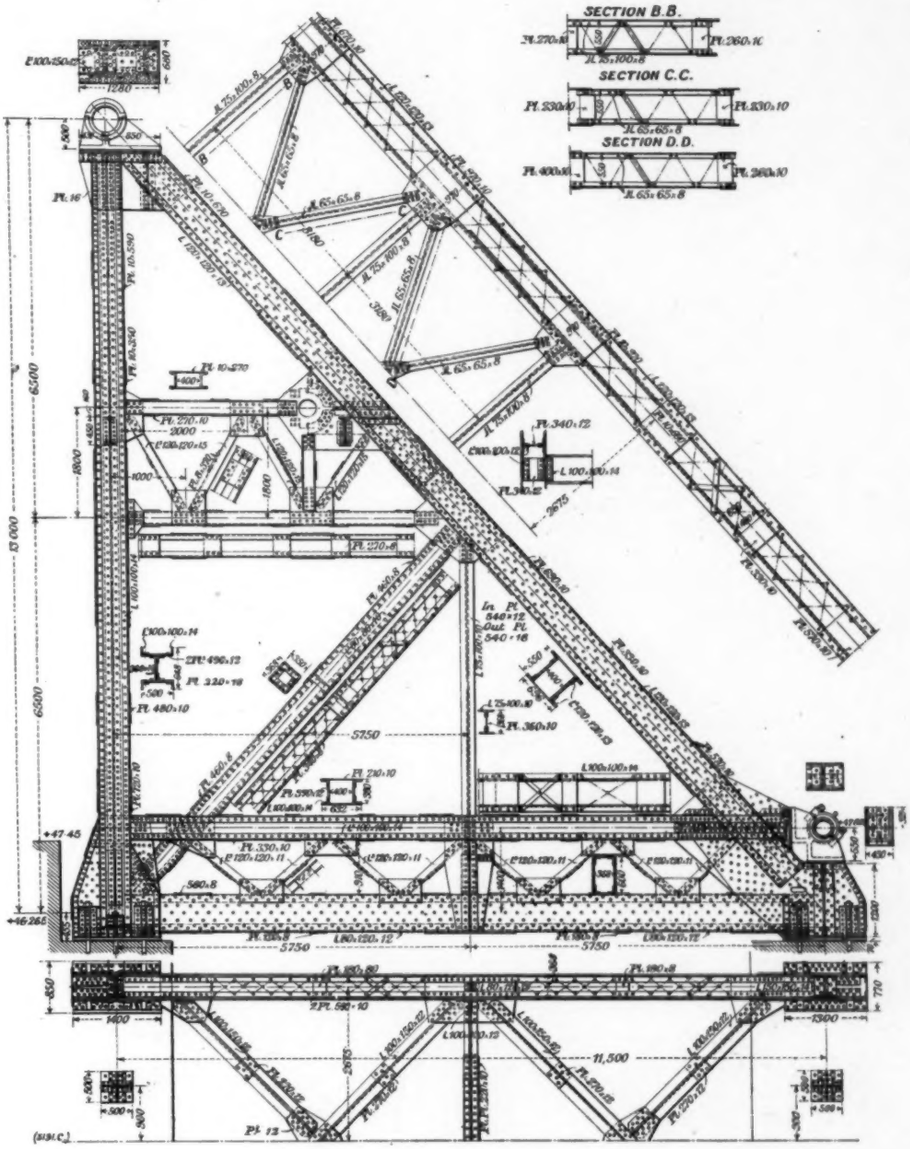


FIG. 54. DETAILS OF TOWER.

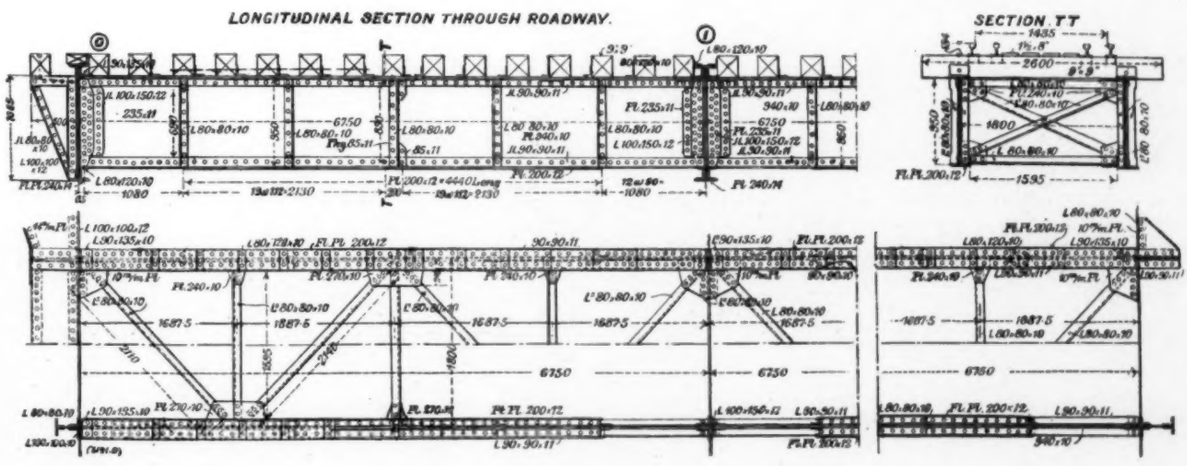


FIG. 57. DETAILS OF FLOORING.

Position of Pivot.	Temp. of Bearing. Deg. F.
$\frac{1}{16}$ in. in front of centre	135
Central	132
$\frac{1}{16}$ in. behind centre	126
$\frac{1}{8}$ in. behind centre	124

The writer of the article in the *Revue B.B.C.* also determines the total load carried per unit width of an infinitely wide block when the viscosity varies according to the law already assumed above. Denoting this total load by $\frac{P}{b}$, he finds that:

$$\frac{P}{b} = \frac{6\,\lambda_1\,Ua^2}{h_0^2}\cdot\psi_1$$

where $\lambda_1 = \lambda_0(1+n)$ denotes the viscosity of the oil at the leading edge, λ_0 being the viscosity at the trailing edge. U is the velocity of motion, h_0 the least thickness of the film and a the length of the block measured in the direction of motion. The function ψ_1 depends on n and m only. Its value for different values of n when $m = 1$ is given by Fig. 3, and when $m = 0.1$ by Fig. 4. Fig. 3 shows that if the viscosity is three times as much at the leading edge as at the trailing edge the load carried is only about eight-thirteenths as much as if the viscosity were constant at its highest value. With $m = 0.1$ the relative carrying power diminishes with varying viscosity in approximately the same degree as with $m = 1$.

In order to test the practical importance of the above conclusions an elaborate series of experiments were carried out in the laboratory of Messrs. Brown, Boveri and Co. To this end bearing blocks suitably pivoted and held, were pressed against opposite faces of a disc rotated by an electric motor. The load imposed on the blocks was provided by a spring and could be varied at will, and provision was also made for varying the position of the resultant pressure on the blocks. The frictional drag on the blocks was accurately measured and the temperatures of the oil film and the pressures developed were measured at a number of different points. The blocks used were five times as wide as long, and it was assumed that along their central section the distribution of pressure would be nearly the same as if the width were infinite. The pressures along this section were measured by drilling holes 1 mm. in diameter through the block and connecting these holes to a manometer. Considerable difficulty was found in making this connection really oiltight, a leak of only five drops a minute proving sufficient to reduce the pressure recorded from 60 atm. to 1 atm. The highest pressure recorded was about 250 atm. or, say, 1½ tons per square inch. Temperatures were measured by thermo-junctions carried through the block to its face. The observations showed that the graph representing the distribution of temperature was a fairly flat curve, and that the change in the viscosity of the oil was in reasonable accord with the assumption on which the calculations already referred to were based. The average thickness of the oil film was deduced from its electrical resistance.

In one experiment in which the load carried was 900 kg. on a square block of 4½ cm. side, this mean thickness proved to be 0·0018 cm., the rubbing speed being 4.2 m. per second. The corresponding least thickness of the film was in this case 0.0008 cm.

Further experiments were made on the coefficient of friction. With an average load of 100 kg. per square centimetre this coefficient was found to vary little from the value 0.002 for surface speeds, ranging from 6 m. up to 36.7 m. per second.

This result was, however, discovered to be due to the higher average temperature and consequent lower viscosity at the higher speeds. Another point examined was the effect of slightly rounding the leading edge of the block. The effect of this was calculated on the assumption that the curve produced by this rounding was a parabola joining up tangentially with the flat surface of the block. The effect was found to be, as might have been anticipated from general considerations, to throw the centre of pressure further aft and to increase the carrying power.

In conclusion, the writer in the *Revue B.B.C.* points out that Michell's calculations show that when a block is of finite dimensions the displacement of the centre of pressure from the centre of figure becomes greater the narrower the block is as compared with its length in the direction of motion. The effect of side leakage is therefore to increase the eccentricity of the resultant pressure on the block, whilst on the other hand the rise in the temperature of the oil tends to decrease this eccentricity.

THE NEW TROLLHÄTTA CANAL.

(*Concluded from page* 658.)

Nine bridges cross the canal, three of them being railway bridges. The Dalbo bridge is a road bridge, with a swing span and a fixed span; the pivot pier is located on the western shore of the canal, and the long arm of the swing span leaves a free opening for navigation of 30 m. (98 ft. 6 in.) breadth, affording ample space for two vessels of 5 m. draught and one of 3 m. draught. The bridge affords a clear headway of 4 m. (13 ft. 1½ in.) above normal water-level, which as a rule will allow the ordinary traffic to pass under it. The opening span rests on a footstep bearing and on a ring of six rollers, running on a roller path of 6.2 m. (20 ft. 4 in.) diameter. The bridge is worked by an electric motor, placed on the pivot pier; the motor is nominally of 40 h.p., and, like all other machinery on the canal, it is driven by current of 25 periods and 380 volts. With a strong wind 60 h.p. is required at starting, but in calm weather only 10 h.p. The bridge can be completely closed or opened in 1.5 minutes. The stationary span on the east side is of reinforced concrete, with an opening of 12.24 m.

The Uddevalla-Vänersborg-Herr Gunga railway bridge has an opening span on the bascule system, said to be the largest of the type in Europe, affording a clear opening of 30 metres. This we describe in detail below.

The Grop road bridge is of similar construction to Dalbo bridge. The swing span has a total length of 53.65 m., of which 35.15 m. (115 ft.) are in the longer and 18.5 m. (60 ft. 6 in.) in the shorter arm. The bridge is worked by a 30-h.p. motor, and can be opened or closed in 1.5 minutes. The stationary span, which is constructed of ferro-concrete, has a span of 12.24 m.

The bridge at Karlsgrav is intended solely for closing the canal when it is being emptied between the bridge and the lock at Brinkebergskulle. This is a precaution against accidents to the lock gate, and also proved useful during the progress of the work when the bed of the canal was laid dry during the winter. The bridge has a span of 34.1 m. (112 ft.) and leaves a free opening of 30.4 m. (99 ft. 9 in.); it is swung by hand by means of a rope.

The Bergslag railway bridge at Trollhättan carries a single line, and consists partly of an unequal-armed swing span, and partly of a stationary span. The swing span has a length of 59.56 m. (159 ft. 2 in.), of which 37.10 m. (121 ft. 8 in.) are in the longer arm and 22.46 m. (3 ft. 6 in.) in the shorter. The bridge affords a headway of 4 m. (13 ft. 1 in.), and is constructed on the rolling-lift system. It is worked by two motors, each of 52 h.p., and it can be opened or closed in 2 minutes. The stationary span is 7 m. and is constructed of plate girders; the piers are monolithic concrete and rest direct on the rock bottom.

The street bridge at Trollhättan is a double-armed lever drawbridge, with an aggregate span of 34.5 m. (113 ft. 12 in.). There is a free navigable opening of 30 m. Each half is worked by independent machinery, placed in machinery chambers one on each side of the canal, each motor being of 40 h.p. The bridge can be opened or closed in 60 seconds.

A bridge has been built for the private railway of the well-known locomotive builders, Nydqvist and Holm, and at their expense; it carries a single line and is a one-armed swing bridge, affording a free opening of 24 m. (78 ft. 8 in.).

The bridge at the upper end of the Akersjö lock carries the road, but is principally intended to serve as a closing bridge for the lock, in case of an accident to the gate.

The closing bridge at Ström is placed at the upper inlet to the lock; this bridge, too, serves the double purpose of a closing device for the lock and of a road bridge. It is of the balanced bascule type. The main girders have a length from the free end to the pivot centre of 18.8 m. (62 ft. 2 in.), and are placed at a distance from centre to centre of 5.76 m., leaving a roadway of 5.2 m. (17 ft.). When used for closing purposes the lock opening is entirely closed by four doors. The bridge is actuated by means of a 24-h.p. motor and can be closed or opened in 30 seconds.

The bridge for the Vänersborg-Herr Gunga Railway already referred to is illustrated on pages 716 and 717, and on Plate LXIII, and is claimed to be the largest of its type yet constructed in Europe. A general view of this bridge is reproduced in Fig. 47, page 716, whilst the side elevation and plan are shown in Figs. 48 and 49, page 717, and end elevations are represented by Figs. 50 and 51, on page 716.

As shown in the elevation and plan, Figs. 48 and 49, on page 717, the structure consists of three spans, of which that on the eastern side of the channel is a simple straightforward plate girder of the deck type. The main span is of the bascule type, with a clear distance between centres of bearings of 42 m. It is hinged at its western end to a triangular frame, the lower member of which spans the approach on that side of the stream, whilst at the top this frame supports the balance lever, and at a lower level the electrically operated gear by which the span is opened and closed. As the plan shows the bridge crosses the channel on the skew, so that the minimum clear width provided for the traffic is 30 m. When closed there is a clear headway above ordinary water level of 1.8 m.

Details of the steelwork are represented in Figs. 52 to 57, Plate LXIII. As shown, the bridge is, in the main, an ordinary riveted steel truss, but has, of course, a rigid lower chord, since a reversal of stress takes place here when the bridge is opened. The trusses are spaced at 5.35 m. centre to centre, and measure 7.6 m. in effective depth. The bridge is intended to accommodate a single line of railway, and to reduce weight has been constructed with an open floor. Considerable attention has been directed to securing a fair degree of torsional rigidity. The cross girders, 1.2 m. deep over flanges (as shown in Fig. 56), are riveted for the full depth to the main truss verticals. To facilitate this, inside instead of outside angles are used for the bottom chord. To stiffen further the connection its depth is augmented by stout triangular gussets riveted both to the top of the cross girders and to the main verticals. Rigid cross bracing is provided both at the top and bottom of the truss (see Figs. 55 and 56). The track sleepers, which are 2.6 m. long, are secured by angles to the top flanges of stringers 950 mm. deep which connect the cross girders as shown in Fig. 57. These stringers are spaced at 1.8 m. centres. Guard rails are provided in addition to the running tracks, and planking spiked to the sleepers as shown in Fig. 57 furnishes a serviceable footway across the bridge. The main span comprises seven panels, of which six are 6.75 m. long, whilst the seventh is 8.25 m. long. The hinges about which the span turns are, it will be seen, arranged at a height of 1.3 m. above the central plane of the lower chords, and a special inclined strut is provided accordingly to transfer the load to each hinge when the span is opened.

At its free end the opening truss rests on flat bearing plates, to which horns are attached to guide the truss as it comes down into proper alignment. There is in addition a conical hole in each of the bearing plates into which a bolt carried on the girder is pushed by rods and links interlocked with the signals. The latter cannot be pulled off to the line clear position unless these bolts are fairly home in their holes. This cannot be done unless the truss rests truly in position, with its rails matching those of the approach span. No holding down bolts are provided since the balance weights have been proportioned and arranged so that there is always a positive load on the bearing at the support pier when the bridge is closed.

The balance lever frame, shown in Fig. 54, is a very stiff structure built up of steel plates and angles. The central planes of the side frames line up with those of the main truss. They are stiffened transversely by the raking struts shown in Fig. 50, page 716. The casting which carries the hinge

BASCULE BRIDGE OVER THE TROLLHÄTTA CANAL AT VANERSBORG.

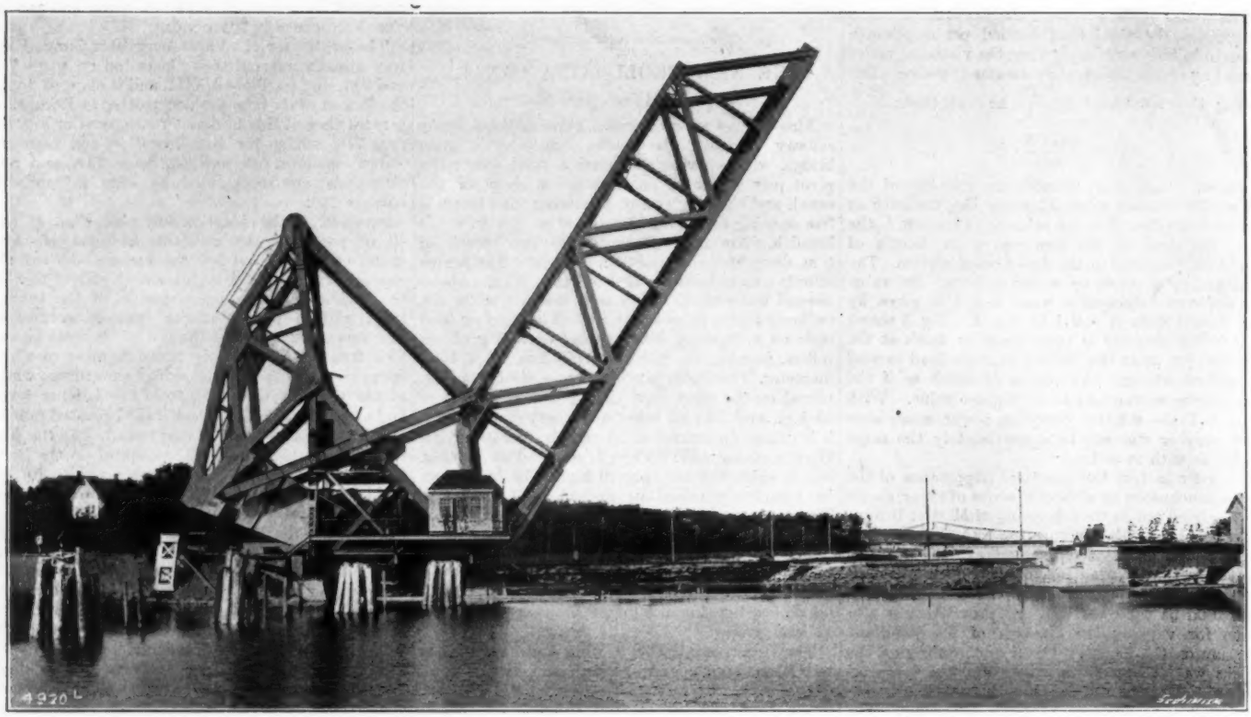


FIG. 47.

pin has, it will be seen from Fig. 54, both vertical and horizontal flanges and is thus thoroughly supported whatever the direction of the applied thrust, without any demand being made on the shearing resistance of the holding down bolts. The casting is sufficiently narrow to fit between the open end plates of the portal strut, which carries the hinge pin as indicated in Fig. 55.

The balance lever is illustrated in detail in Figs. 52 and 53, Plate LXIII. The balance weight is of a somewhat peculiar shape (see Fig. 48, page 717. This was necessitated in part by the necessity of fixing its C. of G. in such a position, that the total load on the operating machinery is practically constant in all positions of the opening span, and in part by the necessity of clearing the rails below, and the links above, by which the span is swung. The counter-weight is in part of iron and in part of 1 : 3 : 5 concrete, and the iron shell was made sufficiently large to enable a substantial increase to be made in the amount of concrete originally provided, should such an addition have proved necessary.

The links which connect the free end of the balance lever with the swing span have their centre lines in the median planes of the trusses. They have to take a maximum tension of 151 tons, and each consists of two latticed channels with inward turned flanges spaced 300 mm. apart. These links fit in between the forked upper ends of the verticals of the portal member, which is, it will be seen from Fig. 55, secured to the other members at the panel point by heavy gusset plates. By this arrangement the pull of the links comes on the truss as directly as possible and with a minimum of distorting strains.

It was not found practicable to secure a similar absence of eccentric loadings in planning the connections for the operating racks. These, however, carry a much smaller load, viz., 28.6 tons instead of 151 tons. They are accordingly coupled up on the outside of the truss and the balance lever frame, which they straddle. These racks are mounted on the under side of the steel channels which form the connecting links. At the one end the links engage with pins on the truss, and for the rest are supported by rollers mounted on the balance lever frame. These rollers maintain the rack in gear with a spur pinion, which is operated by one or other of two 42 h.p. electric motors. The arrangement is best shown in Fig. 48 on page 717. The electric motors are fitted with automatic magnetic brakes and control switches which come into operation as the span reaches either limit of its travel. The time required to open and close the span is 1½ minutes.

The hinges throughout are fitted with bronze bushes, spherically mounted where thought desirable, and special lubricating arrangements have been provided. Access to the hinges both at the top of the frame and at the top of the span is provided by footways properly protected by gas pipe hand railings as indicated.

The bridge piers are of concrete founded on piles as indicated in Fig. 48, page 717.

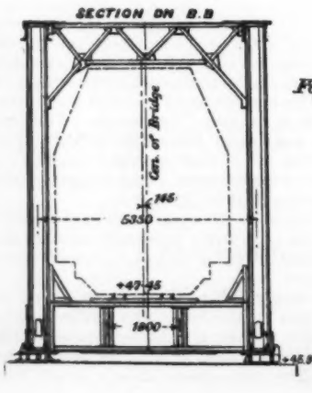


Fig. 51.

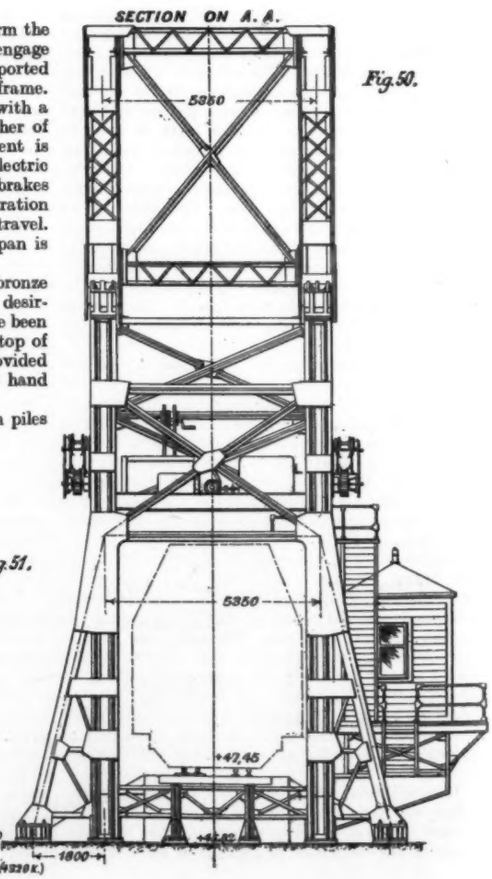


Fig. 50.

BASCULE BRIDGE OVER THE TROLLHÄTTA CANAL AT VANERSBORG.

(*For Description, see Page 715.*)

Fig.48.

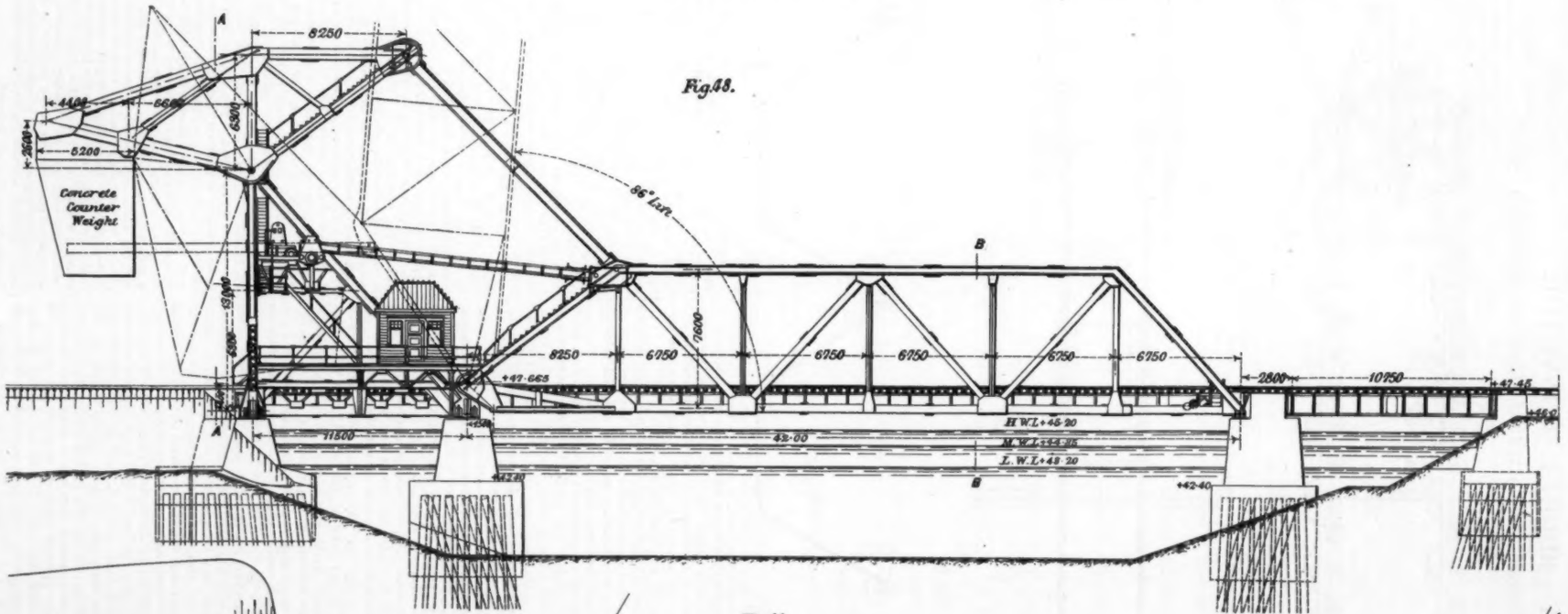
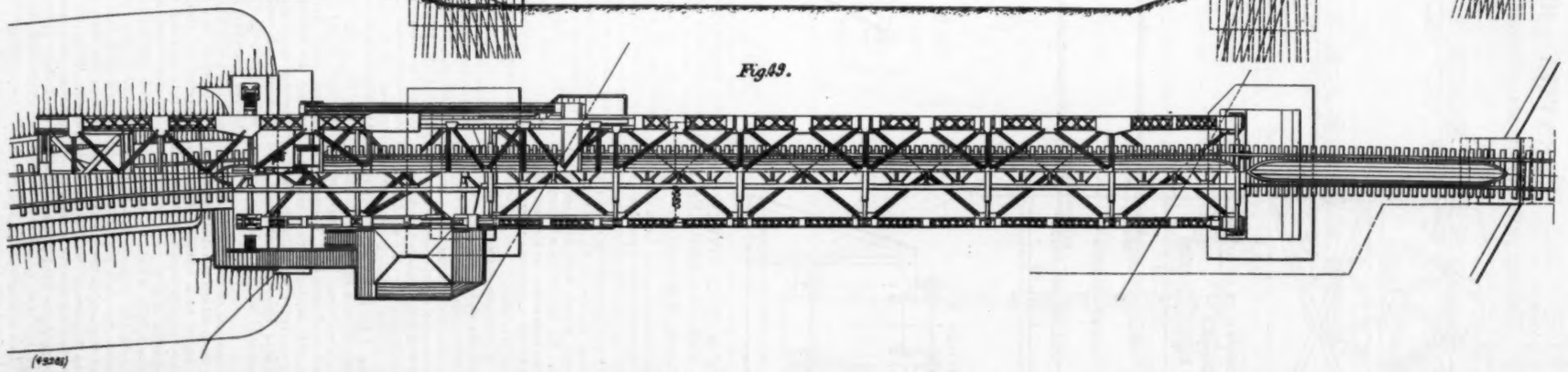


Fig.49.



(4328)

VAPOUR-TENSION FORMULAE. MERCURY.—In recent communications addressed to the Académie des Sciences (*Comptes Rendus*, vol. 166, pages 193, 334, 447, 533, all of 1918), H. Ariès deduces two formulae, which he connects by the table of Clausius, for the tension of the saturated vapour, in the first instance, of any monatomic liquid, for which the power exponent of the absolute temperature n has the value $n = \frac{1}{4}$. It is shown that the vapours of monatomic bodies satisfy the law of corresponding states. That is to say, when the temperature of a vapour is expressed as a fraction of the critical temperature, and the pressure adjusted so as to represent the same fraction of the critical pressure, then the corresponding volume will be the same fraction of the critical volume. Examining the vapour tension values determined by different observers at 13 different temperatures, Ariès finds that in the case of the liquified rare gases, the calculated and observed values are in good agreement; the critical temperatures of krypton, xenon, argon, are respectively 210·4, 287·67, 150·6 deg. C. absolute, and the critical pressures 54·26, 57·24, 48·0 atmospheres. Long-range observations had also been made in the case of mercury, partly for thermometric purposes, and mercury had been found to possess a vapour tension of 162 atmospheres at 880 deg. C. The critical constants of mercury were unknown, but they should evidently be very high. Accepting the values of Ramsay and Young, Caillietet and others, that the tension of saturated mercury vapour is 50 atmospheres at 700 deg. C., and 162 atmospheres at 850 deg., C. Ariès calculates the critical mercury pressure to be 420 atmospheres, and the critical temperature, 1,350 deg. C. absolute. The increase in the vapour pressure of mercury with rising temperatures is certainly very remarkable. Thus it is found that the vapour pressures of 0·129, 0·721, 2·0, 13·8, 102, 162 atmospheres correspond to temperatures of 533, 613, 673, 823, 1073, 1153 deg. C. absolute. Other experimental data further support the critical values stated. Ariès also shows that in the cases of some diatomic liquids, such as chlorine, carbon monoxide, hydrochloric acid and hydroiodic acid, the agreement between observed and calculated values is likewise satisfactory, but that there are anomalies in the behaviour of oxygen, nitrogen, and nitric oxide.

GRAVITY BUCKET CONVEYOR.

CONSTRUCTED BY MESSRS. FRASER AND CHALMERS, LIMITED, ENGINEERS, ERITH.

Fig. 1.

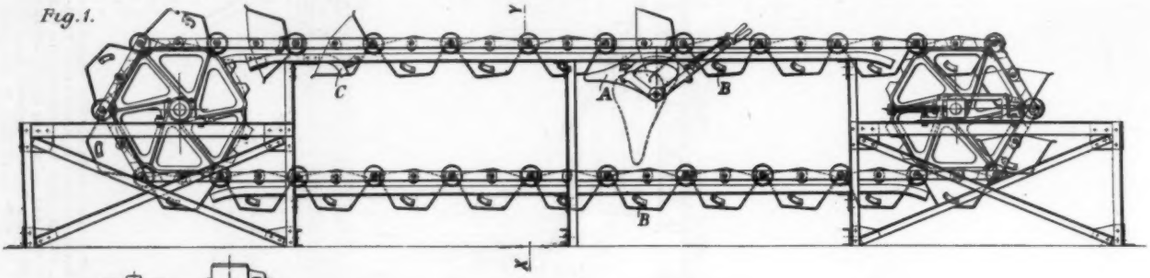


Fig. 2.

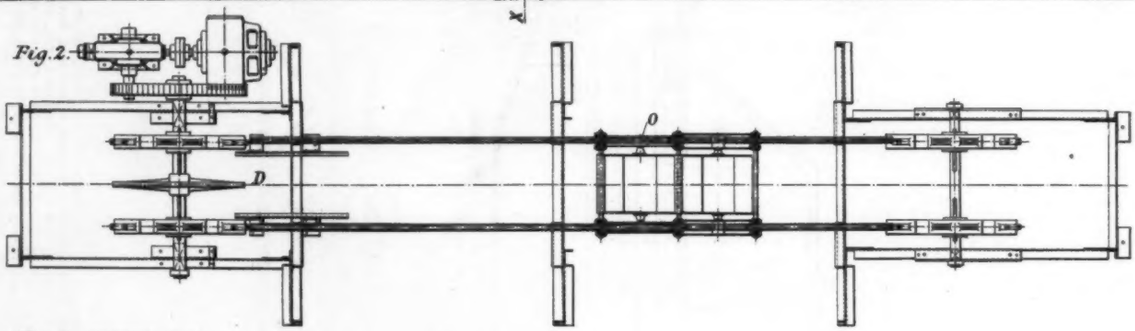


Fig. 3. SECTION X.Y.

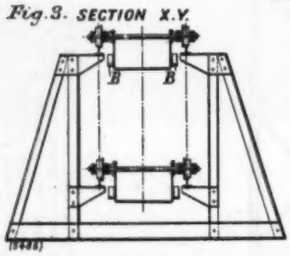
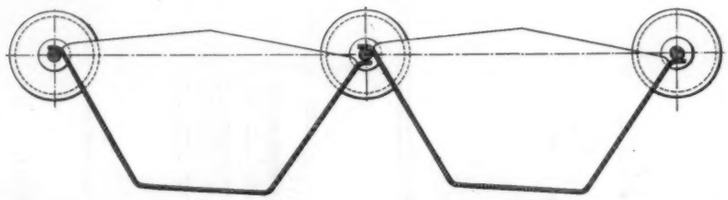


Fig. 4.



THE NEW GRAVITY BUCKET CONVEYOR OF MESSRS. FRASER AND CHALMERS, ERITH.

By G. F. ZIMMER, A.M.Inst.C.E.

A NEW gravity bucket conveyor has been designed by Messrs. Fraser and Chalmers, which promises to be a valuable addition to the conveyors of this type. The writer had recently the opportunity of inspecting an experimental machine at the works of this firm at Erith, and was much struck with the ingenuity displayed in its design. To the casual observer most gravity-bucket conveyors look alike, but the user, who is familiar with the details can appreciate minor details which make or mar such machines.

The accompanying illustrations show this conveyor in plan and two elevations, and it will be seen at a glance that this particular machine has been built solely for the purpose of experimenting; a wise proceeding for a firm who have a reputation to keep up. The conveyor is about 20 ft. long from centre to centre (Figs. 1 and 2), the two supporting rails are 2 ft. 3 in. from centre to centre of the railhead (Fig. 3), the buckets are 18 in. long, 1 ft. 10 in. wide, and 12 in. deep (Fig. 4); they have a pitch of 24 in., and travel at a speed of 50 ft. per minute. The conveyor will handle 50 tons of small coal per hour. The terminal pulleys are hexagonal, and measure 2 ft. 3 in. across the flat. To fill such a conveyor, an ordinary shoot is sufficient, as the buckets form a continuous and unbroken strand, the units of which overlap to prevent leakage.

The tipping device consists of two plates A, which somewhat resemble in their outline the shape of a ham, these two plates are keyed to a spindle at such a distance apart that they engage simultaneously with the two tipping attachment B B on each bucket; a lever is also keyed to this spindle which, by means of a spring catch, engages with two recesses in a segment, which recesses determine the two positions of the tripper when in and out of gear. In the position shows in the illustration, the tripper is in gear, and the conveyor discharges; when the lever is in the opposite direction, the two tripping plates hang down vertically, as shown in dotted lines, and thus permit the buckets to pass undisturbed. This arrangement is simple and inexpensive, and such trippers can, therefore, be placed pretty frequently without adding much to the cost of the installation. They take the place of a travelling tripper, which is generally more complicated, but which has the advantage that it can serve for any position in the length of the conveyor.

In the case of this working model, the tipped buckets discharge direct in the lower run of the conveyor, in actual work, a coal bunker would be situated between the upper and the lower strand.

The chain is composed of long steel links 2 ft. pitch and the joint-pins run across the two chains where two adjacent buckets meet, so that each bucket is suspended in the usual way above the centre of gravity in the centre of each link of the chain. Small running rollers are provided at the end of the joint-pins between the two steel bars forming each link. A glance at the illustration will show that the buckets in their horizontal run are not quite level, this is due to the method in which they overlap, at one side beneath the joint-pin and on the other side above it. This is shown in Fig. 4 to a larger scale. At the joint-pin, where the buckets are swivelled, there are renewable bearing blocks, which pitch with recesses in the sprocket-wheels.

In the article on "Universal Conveyors," which appeared in the issue of January 12, 1917, of this journal, great stress was laid on the importance of getting the buckets of a continuous gravity bucket conveyor to overlap and disengage again at the right moment, and various clever solutions of the problem were described. Since then, with this newest gravity-bucket conveyor, has made its appearance, and as far as it is possible to judge from an experimental machine, the problem has been solved, not only most satisfactorily, but also in an entirely new way. When the buckets approach the end terminal of their horizontal run, they encounter an auxiliary tripper C in a fixed position, which tips the buckets right over bottom-side-up, and as they dip over in this way, they are arrested by coming in contact with a wheel D, upon which they rest for the remainder of their journey round the terminal. Thus, during the period whilst the buckets traverse this terminal, they are no longer free to swing round their pivoted support above their centre of gravity, since the wheel D will not permit of this. By this arrangement, it is quite impossible for the overlapping lips of the buckets to become disarranged.

PREVENTION OF EROSION AT THE FOOT OF A WEIR.—The formation of eddy currents at the foot of a weir may lead to serious erosion of the river bottom, to prevent which various means are adopted. Wooden beams are, for instance, chained to the weir so as to float on the water and to break the force of the falling mass of water. A peculiar remedy is in use on some rivers of Styria, the weirs of which are provided with by-passes for the rafts of wood floating down the rivers; the rafts were caught in the hollows of the river bottom and twisted or broken, especially at low water. To stop the erosion a "Flossfeder," a kind of floating floor, built up of boards and beams, was hinged to the weir bottom; to the surprise of many experts, the hollows already formed begun to fill up again, and no further trouble was experienced. The description of this device by Hofbauer, in the *Zeitschrift des Oesterreichischen Ingenieur und Architekten Vereins*, of April, 1915, induced H. E. Gruner and E. Locher, of Basle, to make model experiments on the prevention of the erosion. The experiments were described in Nos. 3, 4 and 5 of the *Schweizerische Bauzeitung* of 1918, and gave rise to some correspondence in subsequent issues of that journal. The experiments were made, not with weirs, but with sluices, the opening for the water being at the top or at the bottom of the conduit, or in some intermediate position. The bottom of the conduit was covered with hard loam or with concrete, in a sheet or in blocks; the sill, the bottom underneath the weir or sluice and close to it, was always of concrete, and the sill length was varied so that the influence of the wave-form on the bottom could be studied. The hinged floats were attached to the down-stream end of the sill, each float being free to take up its position at the angle (with respect to the horizontal) corresponding to the current conditions. The current rate was determined with the aid of Pitot tubes. The spaces between the longitudinal beams of the float allowed stones to drop through the float, and sometimes part of the bottom was covered with slotted boards. It was found that the sill length should be such that the turbulence quieted down before the water left the sill. A ridge at the sill end, which deflected the strong current, also had a quieting influence, and the floats and slotted bottoms seemed to owe their efficacy to the same reason, that of breaking up the strong eddies. The hinged floats, which must be of sufficient length, were preferable because the float could adapt itself as to level to the stream conditions, and could respond as a yielding obstacle. Irregularly distributed stone blocks at the bottom of the weir, even if relatively big and heavy, were finally carried by the water into the hollows created about them. These experiments are of much interest.

THE STOKES GUN AND SHELL, AND THEIR DEVELOPMENT.*

By SIR WILFRID STOKES, K.B.E. (Hon. Member).

IT has been with great diffidence that I have undertaken to address you to-day as the third Gustave Canet lecturer. The subject which your council has approved of is one about which, three years ago, I knew practically nothing, nor can I to-day claim any deep knowledge which justifies me in standing before you and stating that I have solved any great problems hitherto obscure. My only possible justification is that I have been permitted to introduce into modern warfare a weapon of unusual simplicity and lightness which may possibly tend to exert an influence in the direction of checking the tendency to complication and intricacy which, I fear, is the vogue amongst modern expert designers.

The first Canet lecture, which was delivered by Sir Trevor Dawson in 1909, deals with "The Engineering of Ordnance," involving designs and methods of manufacture which are the outcome of long years of study and experience. The evolution of ordnance must of necessity depend to a large degree upon the process of trial and error, which naturally leads further and further from primitive simplicity. Cause and effect are not always obvious. Minds become set in one direction, and not inclined to retrace steps which have, perhaps under slightly different conditions, not been fruitful of good results.

I, therefore, venture to throw out the suggestion that an investigation on "The Engineering of Projectiles and their Components" could be of considerable service to the nation, because nearly all these problems are engineering problems, in the solution of which the practical manufacturing engineer is the most likely person to be helpful, at any rate, from the production point of view. I hesitate to advocate the addition of still one more department to the long list under the Minister of Munitions, but I venture to predict that if a "Simplification of Designs Department" were seriously and properly set to work, its effect, both on the rate and cost of production, would give equal satisfaction to the supply departments and the Chancellor of the Exchequer.

All this, you may think, has little or no bearing on the subject more particularly before us this evening. My retort, however, is that modern warfare has now developed into one of exhaustion of men and money. Simplicity in design means small cost and quick delivery, not to mention other advantages in the field, and I would therefore ask you to pause, perhaps longer than you otherwise would feel inclined to do, in the consideration of the Stokes gun and shell, as examples of what can be done in one direction, at least, when design is not hampered by precedent or long-established practice.

The Original Conception.—The beginning of the present war found us quite unprepared, more particularly in weapons suitable for trench warfare, and many expedients were resorted to by "Our Contemptible Little Army," having for their object the throwing of high explosives a short distance from one trench to another. When my attention was first called to the position there were four designs in use for service trench howitzer, all more or less slow, heavy, and difficult to manufacture and use. It was suggested to me that we were badly off for "Frightfulness" at the Front and that our men were not having a fair chance. Could I think of anything? What I thought of is shown on Figs. 1 and 2, which are reproduced from the information I sent to the War Office through a friend in December, 1914. Stated shortly, the proposal consisted of a cast-iron bomb with six compartments containing explosive, with a time-fuse which was lighted at the moment of firing, and which was so arranged that each of the six compartments exploded at unequal intervals. At each explosion it was intended that the bomb would be blown into a fresh position, and that, therefore, if it fell into a trench it would be very searching and demoralising. A seventh compartment placed centrally contained a cartridge holding the propellant. The gun, or howitzer, for firing the bombs was a simple tubular barrel with two adjustable legs, thus forming a tripod. The recoil was taken by a cast-iron bowl attached to the base of the barrel.

The lower end of the barrel was provided with a pointed central rod for the purpose of firing the propellant cartridge, when the bomb was allowed to slide down to the bottom of the barrel.

The main features of the scheme thus were: (1) A bomb producing successive explosions. (2) A bomb provided with its necessary charge of propellant ready for firing. (3) A simple gun without moving firing mechanism capable of automatically firing bombs as quickly as they could be fed into the muzzle and allowed to slide down to the spike at the bottom.

From this somewhat sketchy scheme there ultimately emerged the weapon and projectiles which it is my privilege to describe to you this evening, by going through the various stages of evolution which resulted from the experience and knowledge which I gradually acquired. Looking back at what was done, I am tempted to wonder at my temerity in proceeding in the face of the attitude taken up by the experts in the subject, who with one accord "turned down" the proposals I put forward. At that time there was no Munitions Inventions Department, and, so far as I know, no machinery for developing schemes put forward in a crude form. The position to-day is very different from what it was in the early part of 1915, and inventors have now much more chance of obtaining a sympathetic hearing.

The Primitive Gun.—Acting on the courage of my own convictions, however, I had a primitive gun made, at the works of Messrs. Ransomes and Rapier, Limited, Ipswich, out of a piece of drawn tube, and a shell out of a piece of bar, which gave promising results. In fact, the range so much exceeded my expectations that, much to everyone's surprise, my first shot nearly took refuge in a cottage. Other demonstrations followed, from which emerged the following conclusions: (1) The idea of the gun was good, but in need of development. (2) The bouncing cracker bomb was not so good as a single compartment shell. (3) That my knowledge of propellants was so limited that only black powder gave anything like consistent results. (4) That as a burster, black powder should be used, in view of the shortage of high explosive and the desirability of using a cast-iron shell.

Fig. 1. ORIGINAL DESIGN OF COMPARTMENT BOMB.

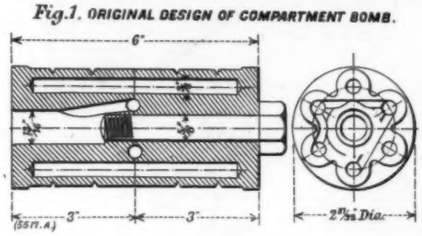
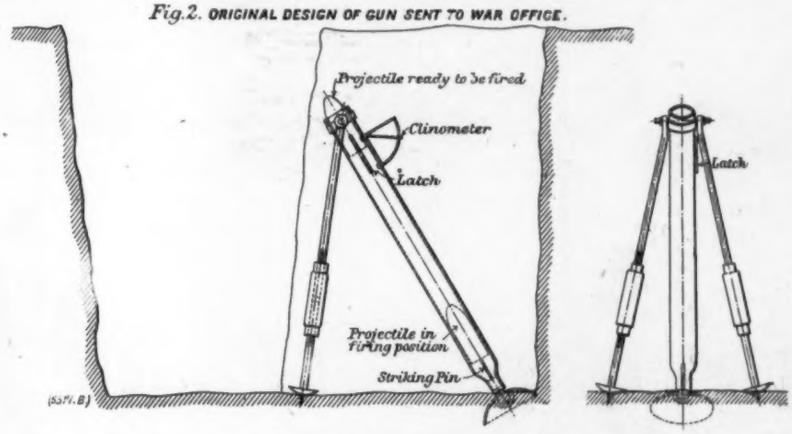


Fig. 2. ORIGINAL DESIGN OF GUN SENT TO WAR OFFICE.



Encouraged by the results so far obtained, and animated by a strong desire to do something to help to win the war, I devoted my week-ends to trials of various sorts, so that I might develop the weapon into something which would be acceptable to the authorities. The problem of the gun itself was not very difficult. I set out with four objects in view: (1) Simplicity in manufacture; (2) simplicity and speed in firing; (3) lightness and portability; (4) quickness and ease in setting up, and change of objective. The first barrels made were bored tubes, but it was evident that if the tubes could be drawn with sufficient accuracy, boring might be dispensed with. Arrangements were therefore made to cold-draw the barrels, and after some preliminary difficulties had been overcome the results were quite satisfactory, even without heat treatment. The lower end was bottle-necked by plant already used in the manufacture of gas cylinders. The design of the front legs involved a good deal of thought. Eventually a simple "A" frame was made, capable of folding up when not in use. The elevating and traversing screws were double-threaded. The traversing screw engaged with projections formed on a gun-metal collar studded on to the barrel. This arrangement worked well if the gun was set up with the legs approximately at right angles to the barrel.

In service, however, it was found difficult to get the gun set up properly, and to meet this a modified leg was introduced of heavier design and with only half the traverse, Fig. 3, page 720. The frame is also arranged to fold up, and to meet the extra weight the legs take apart from the barrel. The traversing screw is hollow, so that a central pin may be inserted through it and the ends of the crutch on the top of the elevating screw. This pin is withdrawn when detaching the legs. Another feature is the introduction of bevel gear for operating the elevating nut. The frame is tubular, instead of the flat bar construction in the original design, and the whole scheme is more on the lines of a machine-gun mounting. The very limited traversing range is the principal drawback, and I have since put forward an improvement on simple lines which has four times the lateral range, without adding to the weight. This is made possible by the introduction of a nest of springs which takes up the shock of discharge, and thus does away with the danger of damage when the gun is badly set. This design is still under consideration, and I fear I must, therefore, not give details of it.

The recoil of the gun when fired is taken by a pressed steel baseplate, Fig. 3. This is set up in the ground as nearly as practicable at right angles to the barrel in its firing position.

In order to increase the traverse three cup-shaped indentations are provided to receive the base of the barrel in alternative positions. A shelf angle helps to keep the barrel in position when the ground is of an elastic character. A rope handle is used when carrying the baseplate.

The Construction of the Stokes' Gun.—Returning to the design of the barrel, it will be noted that the base is closed by a cap screwed on to the end, which is externally threaded for the purpose. Into this cap is screwed a short cylindrical rod projecting into the barrel. The upper end of this rod, or striker, is slightly convex, and a small nipple is formed in the centre. As the face of the striker takes the blow of the projectile when it is allowed to slide down the barrel, this nipple fires the cap of the propelling cartridge, which is placed at the lower end of the projectile. It will thus be seen that there are no mechanisms or moving parts in the base of the gun, and that the firing is automatic, and simply depends on the energy acquired by the projectile sliding down the barrel. It may be remarked in passing that a trench gun, or howitzer, has a high angle of fire, and a projectile will therefore always slide freely down the barrel.

The design of the striker took some time to work out, because I started off on the wrong track. My original idea was that the propellant should be placed in a central cavity in the shell, and that it should blow out the end of the cartridge past a striker having a pointed end. This scheme had two disadvantages. First, the fouling of the gun by the residue from the cartridge ends, and second, the absence of a definite confinement of the propellant which would ensure its burning properly and regularly. When I found out this latter defect I tried a square-ended striker in connection with an enclosed cartridge chamber, with the result that I split open a solid steel shell and nearly burst the barrel. This taught me caution, and thereafter I made a rough-and-ready calculation as to likely pressures before firing any fresh arrangement or propellant. It was some time, however, I am ashamed to say, before I arrived at the proper size and shape of the striker nipple (Fig. 4, page 720), to which I will again refer when dealing with the development of the cartridge container.

The barrel is formed of a cold-drawn steel tube, the thickness being determined by the pressure developed by the propellant near the base. There is a very considerable expansion chamber, which reduces this pressure to only about 1¾ tons per square inch in the case of the 3-in. gun. This expansion chamber is important, because if ballistite (the propellant adopted) is confined in a chamber which it completely fills a pressure of over 40 tons per square inch is generated. The cubical contents of the expansion chamber in relation to the contents of the cartridge are such that this 40 tons is reduced down to 1¼ tons when acting on the walls of the gun and projectile. A 3-in. barrel, turned down for a length of 2 ft. to a thickness of only ⅛ in., was proofed with 10 rounds of full charge projectiles, and showed no sign of deformation.

A light canvas cap is provided to cover the muzzle when the gun is not in use to keep out rain and dust. In the original guns a bolt was provided near the muzzle, projecting inwards and capable of withdrawal by a lanyard. Thus a projectile could be placed in the gun and fired from a distance by withdrawing the bolt supporting it. This firing from a distance followed the practice of mortars then in use, but a little experience showed the bolt to be not only unnecessary but inconvenient for rapid fire. The present guns, therefore, have no safety bolts, and rapid fire is facilitated. The speed of firing is measured by the skill displayed in dropping the projectile down the gun and in the supply of projectiles being maintained. It is quite easy to fire from 20 to 30 rounds per minute, and I believe a record team have fired off 43 shells per minute. There is no danger of the hand being hit by the projectile.

Range Variation.—The range variation can be obtained in four ways: (1) By varying the angle; (2) by varying the propellant charge; (3) by varying the expansion

* Third Gustave Canet lecture, delivered before the Junior Institution of Engineers, on Monday, June 24, 1918.

chamber; (4) by providing escape exits for the propellant.

1. Varying the angle within limits is the simplest. The maximum range is obtained with the barrel at about 45 deg. To shorten the range, say, 50 per cent., the angle must be increased to about 72 deg., but at this angle the height of flight may make the effect of wind a seriously disturbing factor on the accuracy.

2. It is therefore necessary to have resort to varying charges as well as varying angles. I originally contemplated four different charges, but ultimately these were reduced to two for the sake of simplicity.

3. To vary the expansion chamber involves alteration to the length of the striker. This is not convenient, and after a few attempts was abandoned as impracticable. It was found, however, that there was a striker

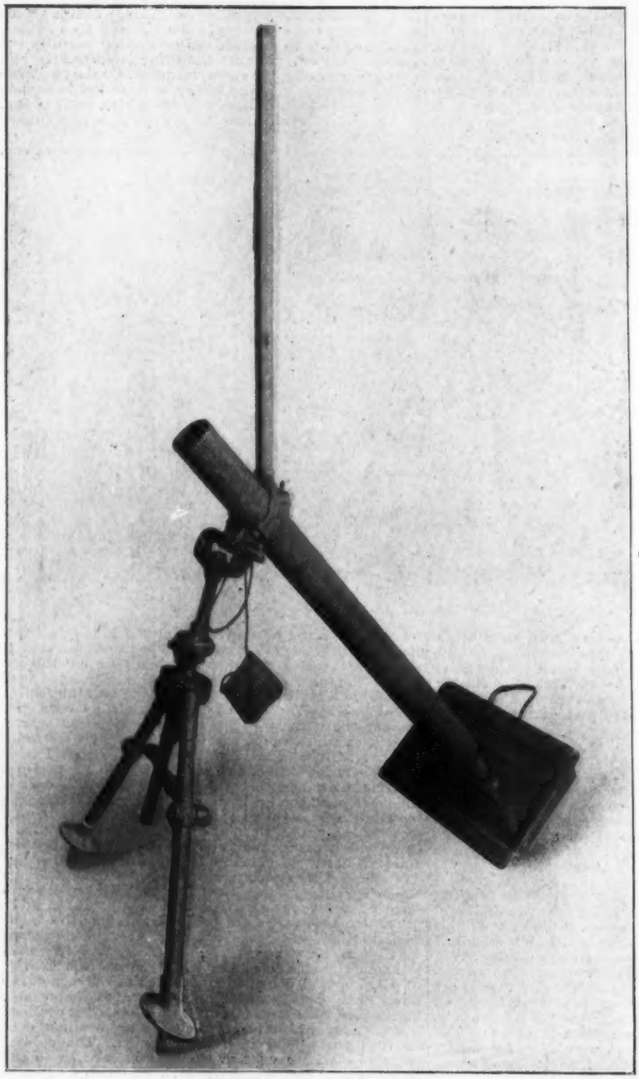


FIG. 3. SECOND SERVICE PATTERN GUN.

length which gave the maximum range. Increasing the pressure by shortening the striker, did not further increase the range, owing to the greater escape past the projectile, due to the windage.

4. The last alternative, viz., of providing means for allowing the escape of part of the propellant pressure was also abandoned for several reasons, amongst the most important being: (a) Avoiding unnecessary complications; (b) the inconvenience from excessive noise when firing; (c) the objection to having openings at the base when firing in water-logged trenches; (d) the difficulty of definite and quick control.

In order to provide an easy method of getting on to an objective a simple clinometer was designed, Fig. 5. The arm carrying the bubble gives two sets of readings. On one side the range in yards obtained with the full charge is shown, together with the time of flight for fuse setting, and on the other, similar information in connection with the lesser charge. Latterly, however, owing to the multiplicity of charges and other alterations, range tables have to be used in conjunction with a simple clinometer reading angles only. In order to enable the gun, when set up in a trench, to be laid on an object, a telescopic periscope was provided to engage with a socket on the collar belonging to the mounting. This socket has its axis parallel to the axis of the barrel. Thus, when the periscope is vertical (as shown by the spirit bubble), any object visible through the periscope and falling on the centre lines is in the direct line of fire. In practice, I understand that sufficient accuracy can be obtained without the use of a periscope.

The Projectile.—Having dealt so far with the details of the gun, I will now return to the projectile. It will be remembered that my original idea was to have a projectile formed with a number of chambers holding explosive, which should be arranged to give successive explosions in different positions. The first conception is shown in Fig. 6. It is formed in two parts, secured by a central bolt and arranged with time fuse connections between the chambers. I very soon found this scheme impract cable, as the first or second explosion opened the joint, and the remaining chambers went off simultaneously. I next tried a bundle of separate cast-iron chambers, with external fuses, Fig. 7. This also was a failure, as the violence of the first explosion broke up and fired the rest. By this time I was officially told that the "bouncing" idea was not acceptable.

For my own satisfaction, however, I made a final effort, which turned out fairly satisfactory. This device consisted of four concentric chambers holding black powder, and formed by fitting cast-iron cylinders one outside the other and so shaped that the ends were closed (Fig. 8). A short length of time fuse was attached to each chamber of such relative lengths that the explosions took place successively, beginning with the outer chamber and finishing with the centre one. This scheme had the desired effect of successive bouncing explosions, but the construction was too complicated and heavy to encourage the attempt to obtain its adoption. From this time onward I devoted my attention to the production of a shell having sufficient accuracy and a single bursting charge. As the gun barrel was not rifled, the projectile, when fired very quickly, began to turn over in its flight, and the question arose as to whether or not some arrangement should be made to make it fly end on. Various experiments were tried, but nothing gave such uniform results as the shell shown in Fig. 9, which has a body formed more or less on stream lines, with wings at the tail end. For various reasons, however, this design was not adopted, although latterly there seems to be a movement in the direction of using a cast-iron shell with wings. In this connection it may be of interest to show graphs taken from a model of the standard shell, with an air blast carrying pigment in the form of very fine spray. These graphs are shown in Fig. 10, and, although not absolutely conclusive, are

FIG. 4. CORRECT DESIGN OF STRIKER.

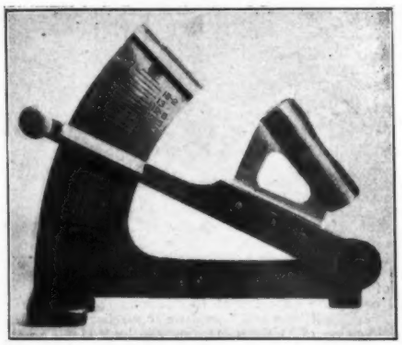


FIG. 5. CLINOMETER; LONG-RANGE READING

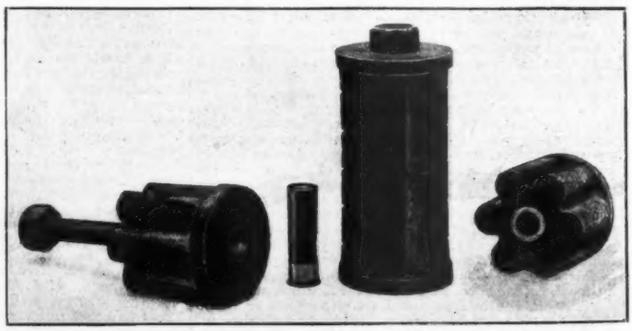


FIG. 6. ORIGINAL C.I. SHELL (DISSEMBLED).

interesting as showing the stream lines. I next experimented with a simple cylindrical cast-iron shell, shown in Fig. 11, which held about 1 lb. of black powder, and the fragmentation of which was quite good. This design involves very little machining, and is simple and cheap to make.

The final design adopted, however, is shown in Figs. 12 and 13, and consists of a piece of wrought steel tube forming the body, with screwed-in ends, thus giving a very light construction, capable of holding about three times as much high explosive as an 18-pounder service shell. The screwed-in ends have to be machined to fine limits as regards diameter, so that the windage losses may be fairly constant. When developing these types of shell, I was confronted with many difficulties, owing to my previous inexperience. To obtain regularity, or even certainty with the propellant, involved becoming acquainted with the fundamental principles, such as, that properly to burn a propellant a definite pressure must be generated.

The Propellant.—In a shot gun, the propellant is confined by the inertia of the shot in front of it, and

being also confined in other directions, the necessary conditions are present for uniform burning. In my case, however, the conditions were different, as, having abandoned the idea of allowing the end of the cartridge

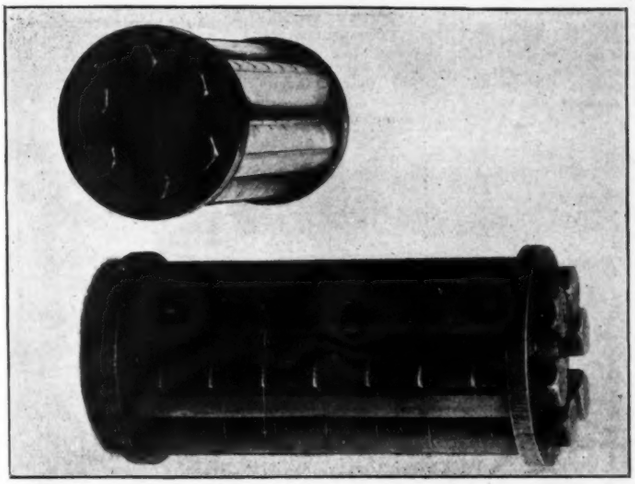


FIG. 7. C.I. COMPOUND SHELL WITH SIX CHAMBERS.

size, number, and position of these holes which would avoid one or other of the following objections: (1) Bursting the container; (2) blowing out the end of the cartridge; (3) not igniting the propellant at all, or not with certainty. It soon became evident that the cartridge container must be made thicker than hydraulic tubing, and that the material used must be of good quality, to avoid splitting open, as the pressure must be at least 2 tons per square inch. The diameter of the holes must be such that before the side of the cartridge case gives way a sufficient pressure was generated to ensure burning the complete charge thoroughly. Various makes of cartridge cases were tried, and those made by Eley Brothers, Limited, were found by far the best.

In addition to the size and number of holes, it was found that the position of the nearest holes to the ignition end had marked effect on the results. Another difficulty arose from the amount of charge which had to be ignited, and which required a cap with more fulminate of mercury than the normal sporting cartridge cap. This difficulty was at first accentuated by the fact that owing to the wrong shape of the striker nipple, the anvil of the cap was sometimes displaced so as partly to close the flash hole, thus giving short range or misfire. Primers of various sorts and amounts were tried and abandoned. In the case of the 3-in. gun a No. 12 bore size is used, and in the 4-in. a No. 4 bore. These cartridges are coloured differently, according to the charge they contain, and are varnished to make them waterproof. A distinctive mark in the end wad facilitates recognition in the dark, and the end turnover is slightly dented, which ensures a tight fit in the cartridge container,

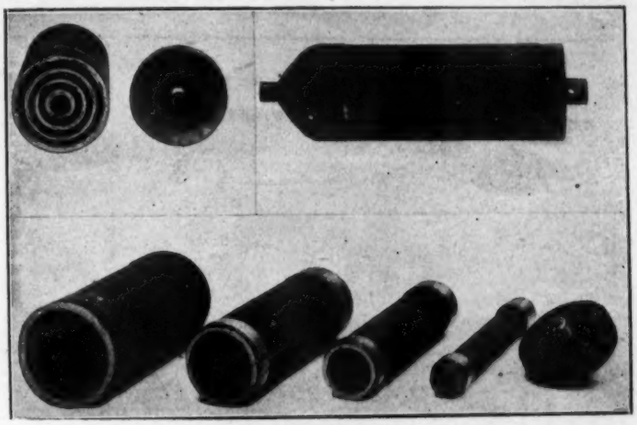


FIG. 8. C.I. SHELL WITH FOUR CONCENTRIC COMPARTMENTS.

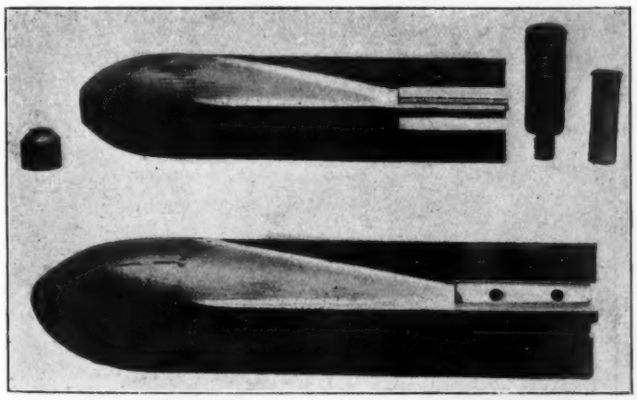


FIG. 9. C.I. SHELL TO FLY END-ON.

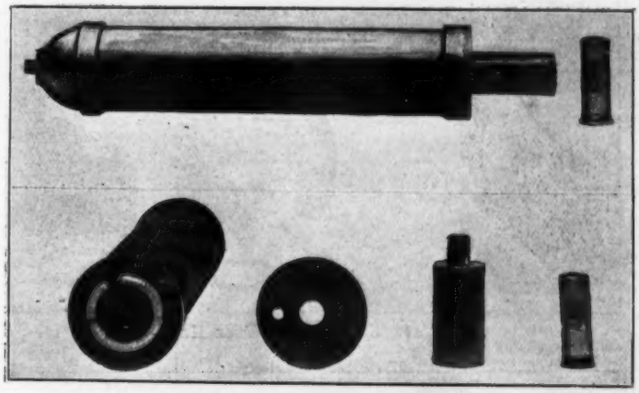


FIG. 11. C.I. SHELL AND FUSE FOR BLACK-POWDER BURSTER.

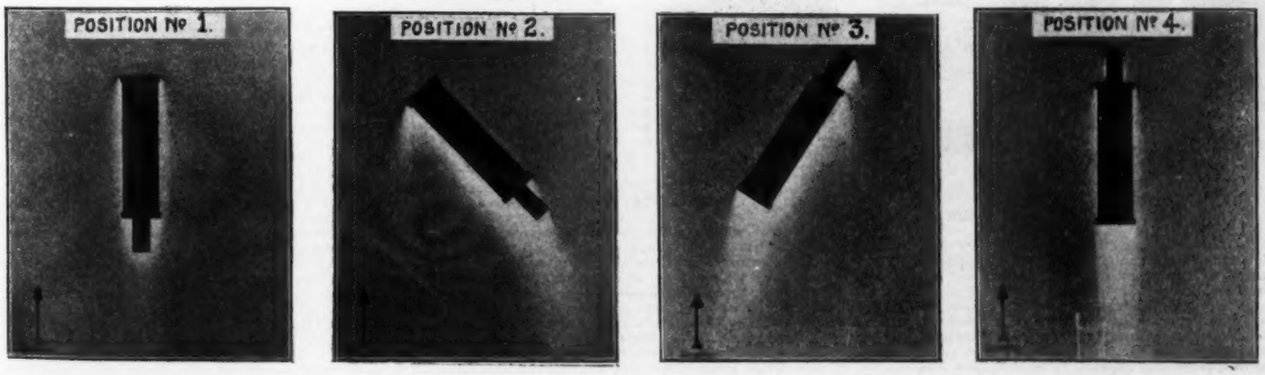


FIG. 10. AIR RESISTANCE TO STOKES' SHELL; NO FUSE HEAD.

to blow out, it became necessary to provide vents in the side walls. Starting with an ordinary sporting cartridge case, I placed it in a tube or "cartridge container," projecting from the base of the projectile, and provided it with holes. The next difficulty was to determine the

notwithstanding variations in the relative sizes of the cartridges and containers. Many of the initial difficulties arose from a lack of uniformity in the results. These variations I ultimately found were due to changes in temperature. In warm weather the cap and propellant are more active. I was just on the border line between success and failure, and I frequently found that defects which I had eliminated one day reappeared the next under colder conditions. These uneven results were very disconcerting and difficult at first to understand.

When deciding upon the best kind of propellant, practically all the available smokeless powders were tried, but Nobel's sporting ballistite proved in every way the best for the purpose, and was ultimately adopted.

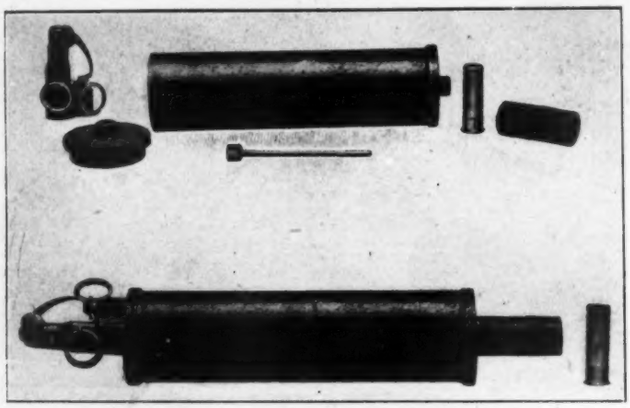


FIG. 12. SERVICE 3-IN. H.E. SHELL AND FUSE.

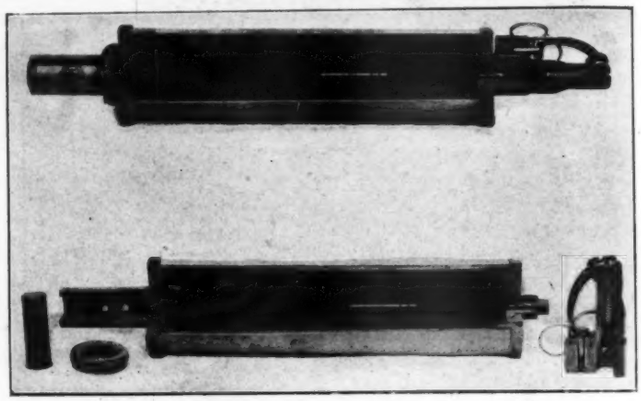


FIG. 13. 3-IN. H.E. SERVICE SHELL IN SECTION.

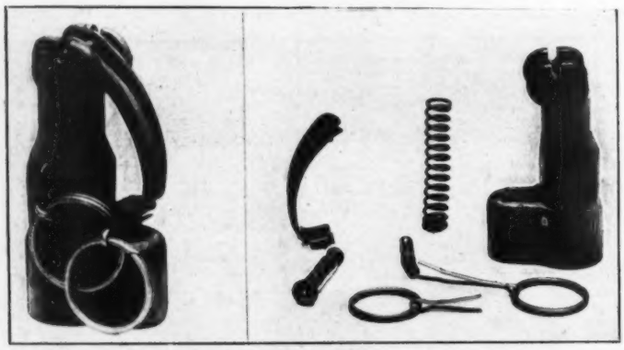


FIG. 14. SERVICE TIME-FUSE HEAD.

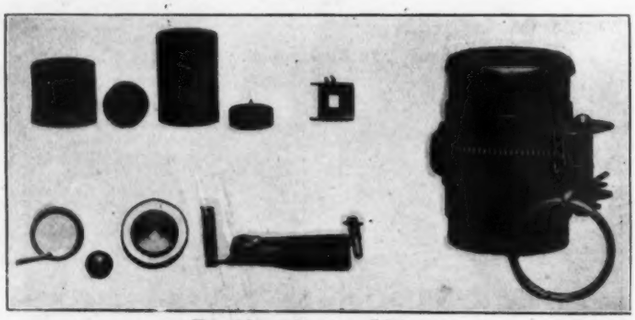


FIG. 16. "ALLWAYS" FUSE.

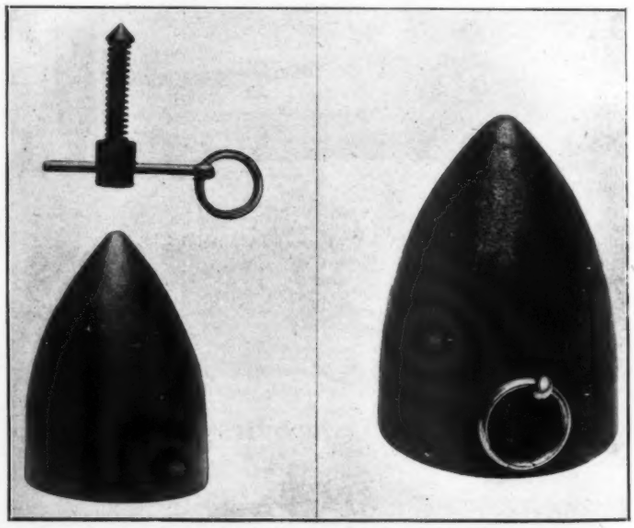


FIG. 15. ANOTHER TIME-FUSE HEAD.

Ballastite is a combination of nitro-glycerine with gun-cotton. It is rolled into thin sheets and cut up into squares and coated with graphite. It is very quick burning, leaves no residue, and gives about 27 yard-lb. range per grain. In common with other propellants, its thickness governs the speed of burning, and some difficulty was at one time experienced on account of the makers departing slightly from their previous practice in this respect, resulting in the cartridge end blowing out. With ballistite there is very little flash at the muzzle of the gun, even with the original full charge. This is doubtless due to the low muzzle pressure. When experimenting with black powder, I was struck with the small amount of smoke produced, and this I attributed to the large air chamber in which the powder was burnt. The fouling of the gun, however, made black powder unsuitable.

Increase Range of Gun.—When the gun was first issued for service, a range of about 430 yards was considered sufficient. Under altered fighting conditions, however, it became desirable to increase the range, and this has been done by adding extra charges, made up in the form of rings, which can be slipped over the outside of the cartridge container. The propellant contained in these rings is somewhat thicker than the ballistite in the cartridge, in order that the rate of burning may be so slow as not to add materially to the initial pressure in the base of the gun. The muzzle pressure, however, is considerably increased, as also the flash. The fabric material from which these rings are made tends to foul the gun, and must also be kept dry. An alternative method, which does away with these disadvantages, has been put forward, and is now under consideration. In order that the shell may slide with sufficient freedom down the barrel, a windage has to be provided, which in the case of the 3-in. gun amounts to 2½ hundredths of an inch. This windage reduces the range somewhat, but, as the amount of propellant used is trifling, the loss is not material. Experiments were made, using thin flanged copper gas checks attached to the base of the shell, and shaped like a pump leather. It was found that the range was increased by about 30 per cent., but that the accuracy was not improved, probably owing to variations due to the friction set up in the barrel.

The Time Fuse.—The next problem which required solving was the best means of bursting the shell by some form of time fuse. I started to work, using a short length of projecting Bickford fuse, which should be cut to the required length and lighted at the moment of firing. Bickford time fuse is commercially used for blasting operations, and is a waterproof flexible construction of various makes, with a black powder core woven with strands of hemp. When lighted, it burns like a squib, generally at the rate of about ⅜ in. per second, if the end is free for the escape of the products of combustion. In the case of the cast-iron shell shown in Fig. 11 a Bickford fuse is contained in an annular space formed in the base of the shell. One end of the fuse projects into the powder filling in the shell, and the whole was bedded in plaster of Paris. A washer, having a hole in it immediately over the Bickford ring, is capable of rotation when the cartridge container is slightly unscrewed. The edge of this washer is marked in seconds relative to a zero mark on the shell flange. A piercing tool is inserted through the hole in the washer when the desired setting is made, thus cutting through the outer fabric of the Bickford fuse, so that on firing, the flash of the propellant lights the fuse at the desired spot. Many experiments were made with this arrangement, and some very good results obtained. No prematures were experienced, and with a black powder burster the fragmentation was excellent.

When, however, high explosive is used, it is necessary to adopt a detonator, and a fresh arrangement is necessary. This consists in providing the nose end of the shell with a thin detonator tube projecting into the high explosive filling, into which the detonator and Bickford fuse can be inserted. The upper end of the Bickford fuse is fixed in a chamber containing a cap, which on being struck, lights the Bickford, the length of which determines the interval which elapses before the detonator explodes. It should be noted that detonators are occasionally very sensitive, and every precaution should therefore be taken to avoid a premature. In the arrangement described, the detonator is fired in the direction which still further tends to compress the fulminate of mercury and not to break it up. This is the only safe way to fire a detonator, and the fact that it is crimped on to the Bickford fuse, which is the elastic member which starts it in motion when fired, still further adds to the safety.

The method of firing the cap which lights the fuse is shown in Figs. 14 and 15. The mechanism in the earlier arrangements was very similar to that of the Mills hand grenade, viz., a central bolt with a pent-up spiral spring coiled round it. The central bolt was maintained in the firing position by a lever which, when uncontrolled, flew outwards and released the central bolt. The end of this lever, however, was maintained in its proper position by a set-back bolt, which, in turn, was kept in position

by a coiled spring beneath it. A safety-pin was arranged, so that the set-back bolt could not be displaced and the lever released until the pin was withdrawn. On firing, the inertia of the set-back bolt compressed the spring behind it sufficiently to allow the lever to be released, which then flew off, allowing the central bolt to strike the cap at the end of the Bickford fuse, which was thus lighted.

Fig. 14 shows the service pattern as issued. The mechanism is precisely the same, but the fly-off lever is exposed instead of being shrouded by the body of the fuse, and is therefore liable to be knocked off with rough usage. Fig. 15 shows a better arrangement, in which a pent-up spring is dispensed with, as also the fly-off lever. It was, however, never adopted, as the design shown in Fig. 14 had already been put in hand. A safety-pin passes through the head, and, until it is withdrawn, prevents the central bolt striking the fuse cap or the shell sliding down the gun. The coil spring round the central bolt is of such strength that, on firing, the inertia of the central bolt is sufficient to cause it, by compressing the spring, to strike the fuse cap. In case of a partial misfire, the shock of discharge is not sufficient to compress the spring, and the cap is therefore not struck. Rough usage in one direction only would tend to ignite the cap, and the strength of the spring is such as to cover all reasonable risks. There are certain difficulties with the use of the Bickford fuse, one of them being the uncertainty of lighting it by means of the fuse cap, more particularly if damp. This can be got over by coating the end of the fuse with fine black powder, applied with a celluloid solution, such as collodion. In order that the best results may be obtained from the Bickford fuse, a free outlet or vent should be provided for the escape of the products of combustion. The fuse should not be bent about before use, otherwise its speed of burning is increased. The crimping both at the detonator and cap end should be carefully carried out in order not to restrict the outlet of the gases. On the other hand, the crimping should be effectively done in order that the necessary adhesion is provided between the parts to be set in motion at the moment of firing.

Percussion Fuse.—Another form of fuse, called the "Allways" fuse, is shown on Fig. 16. This is a percussion fuse, and, therefore, requires no time setting. The construction of the fuse includes a metal ball confined in a chamber having double conical walls, one wall being formed by a movable member carrying a needle point, which can pierce the detonator or cap, which lights an instantaneous fuse or powder puff in connection with the main detonator, which sets off the high explosive charge. A safety device only allows the ball to function after the projectile has been fired from the gun. As its name implies, this fuse operates when the shell reaches the ground, whatever the position of the shell may be. This fuse was originated by the authorities to obviate the trouble of preparing different lengths of time fuse, and has been recently considerably improved.

Fig. 17 shows another method of getting over the same difficulty, but this, however, was not adopted. In this arrangement, the length of Bickford fuse sufficient to give the maximum time required is placed in a soft metal sheath, which is suspended by a cross pin near the nose of the cast-iron body. The upper part of the fuse is doubled back on itself, and a small cartridge case is crimped on to the end, the cap of which projects slightly from the face of the case. Upon firing, the set-back is sufficient to tear the cross pin through the soft metal case, allowing the cap to strike against the nipple of the shell, thus lighting the fuse. When it is desired to vary the time of burning, a piercing tool is placed over the cast-iron body (which has a slot in it, exposing one side of the fuse), and a piercing pin is forced through both adjacent lengths of the fuse. When the fuse is lighted, therefore, it burns until it reaches this hole, which, forming the nearest exit, flashes across to the other length of the fuse, thus short-circuiting the upper part of the fuse and shortening the time of burning. The piercing apparatus is also shown on Fig. 17, and is graduated so as easily to give the desired results. A considerable number of experiments showed that this fuse was quite reliable, but the advent of the "Allways" fuse decided the authorities that such an arrangement was not necessary, and it was therefore not adopted.

At the present moment there are three sizes of Stokes' guns, with their appropriate ammunition, in use, viz., 3¼ in., 4¼ in. and 6 in. Fig. 18 shows a 2-in. gun, with a self-contained base arrangement for taking the recoil, which, being hemispherical, facilitates variation in the direction of the barrel without readjustment in the ground. This gun would readily fire 4-lb. projectiles a distance of 200 yards to 300 yards, and should form a very handy weapon for attack. The gun was never adopted, but I have thought it of sufficient interest to refer to. The 3¼-in. gun fires a high explosive projectile weighing 10¾ lb. to a maximum range of 800 yards. The 4¼-in. gun is mostly used for smoke and gas shells of various sizes and weights, the maximum range being 1,060 yards with a 26-lb. shell. A gas shell is shown in Figs. 19 and 20. The 6-in. gun fires 47-lb. high explosive projectiles, the maximum range being 1,420 yards. The shell is of cast-iron, with wrought-tail wings.

Having now described the various stages which were passed through when developing the gun and its porjectiles, I venture to hope that the history has not been altogether uninteresting. The weapon, as it is now used, seems, in the light of present knowledge, very simple and obvious, but, like most simple things, the arrival at the final stage involved much patient effort, which was rendered more difficult by the apparent lack of data to work upon. It is, however, consoling to know that, in the end, facilities have been provided to our armies and those of our Allies at the Front, by means of which, with a comparatively short training and experience, results may be obtained which hitherto were not possible. This result is largely due to the interest taken in my efforts by certain officers, and also to the facilities and support placed at my disposal by Messrs. Ransomes and Rapier, Limited, Ipswich, who made all the experimental material used. I welcome this opportunity of thanking all those who have helped me to a successful issue.

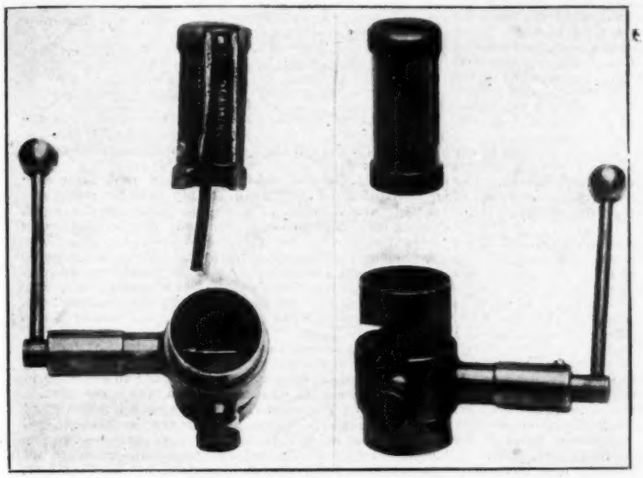


FIG. 17. VARIABLE TIME-FUSE AND PIERCING APPARATUS.

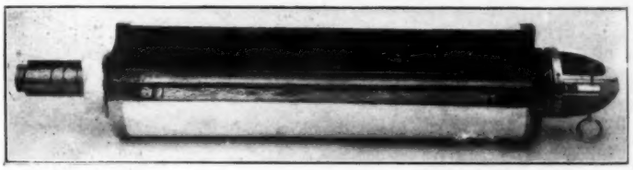


FIG. 19. 4-IN. GAS SHELL WITH FUSE, CARTRIDGE AND EXTRA CHARGE RING.

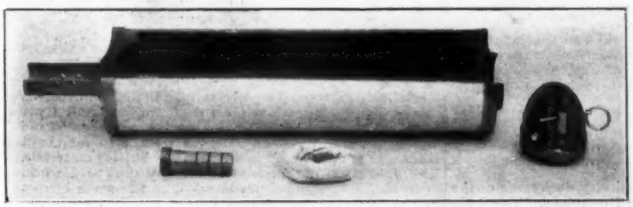


FIG. 20. 4-IN. GAS SHELL WITH FUSE, &C., REMOVED.

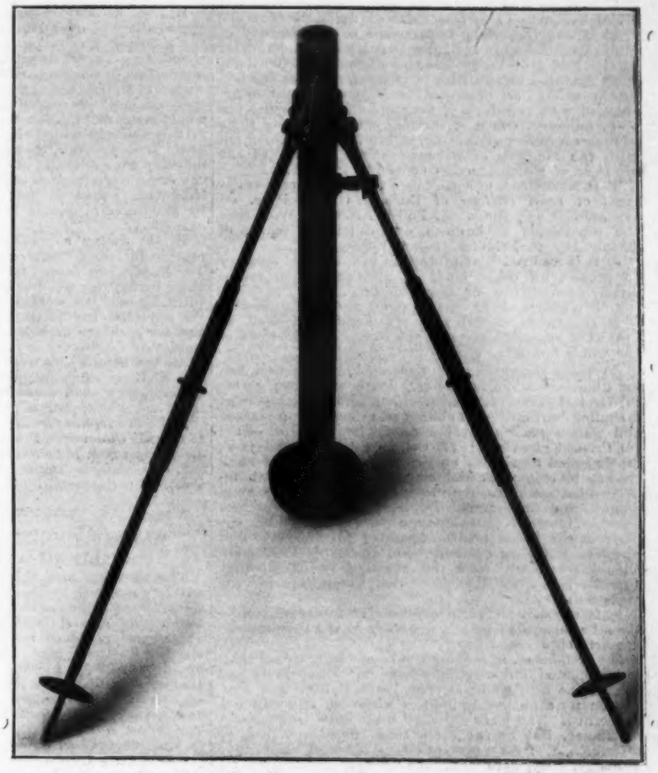


FIG. 18. 2-IN. GUN WITH SELF-CONTAINED BASE.

THE AMERICAN COKE SUPPLY.—According to *The Iron Trade Review*, Cleveland, Ohio, shipments of coke on May 21 were moving satisfactorily to blast furnaces, and there were practically no complaints of shortage.

LOSSES OF MERCHANT TONNAGE.—The Secretary of the Admiralty makes the following announcement:—The losses of British, allied and neutral merchant tonnage due to enemy action and marine risk during the month of May, 1918, compared with preceding periods are set out below:—

Gross Tonnage.

Period.	British.	Allied and Neutral.	Total.
Second quarter, 1917	1,361,870	875,064	2,236,934
Third quarter, 1917 ..	952,938	541,535	1,494,472
Fourth quarter, 1917	732,880	409,954	1,272,843
First quarter, 1918 ..	695,380	447,350	1,142,730
April, 1918	226,108	85,348	311,456
May, 1918	224,735	130,959	355,694

The losses for marine risk have been unduly heavy for May. The tonnage of steamships of 500 gross tons and over entering and clearing United Kingdom ports from and to ports overseas was as under:—

Period.	Gross Tons.
January, 1918	6,336,663
February, 1918	6,326,965
March, 1918	7,295,620
April, 1918	7,040,309
May, 1918	7,777,843

This statement embraces all United Kingdom seaborne traffic other than coastwise and cross-Channel.

THE SOCIETY OF GLASS TECHNOLOGY.

THE June meeting of the Society was held in the University, Sheffield, on the 19th inst., the President, Mr. W. F. J. Wood, occupying the chair. As the result of the discussion at the London meeting, on May 15, on "The Glass Industry After the War," Mr. S. M. Jenkinson, M.B.E., proposed the following resolutions :—

1. It is resolved that, in the opinion of the Society of Glass Technology, it is considered desirable that the Optical and Glassware Department of the Ministry of Munitions, including the Inter-Departmental Committee of the Board of Trade and the Ministry of Munitions, shall continue in existence for some time after the end of the war as an organised Government Department, charged with the duty of fostering and developing the glass industry, which is showing such promising signs of progress towards efficiency, and to work in conjunction with the Ministry of Reconstruction, so long as the Ministry of Reconstruction continues to exist.

2. It is resolved, in accordance with the recommendations of Lord Balfour of Burleigh's Committee, on Commercial and Industrial Policy After the War, that the prohibition of imports, except under licence, of certain key varieties of glass is necessary.

3. It is resolved that protection of tariffs is necessary to protect all other kinds of glassware from unfair labour competition and from dumping.

4. It is also resolved that, in the opinion of the Society it is considered desirable that a Federation shall be formed of representatives of the eight trade sections of the whole industry, viz. :—

(1) Table and decorative glass, including shades, &c., for illumination purposes; (2) Plate and sheet glass; (3) Optical glass; (4) Chemical and scientific glassware, including burners, lamp chimneys, miners' lamp glasses, and gauge glasses; (5) Electric lamp bulb glass; (6) Pressed glassware; (7) Common bottles and jars; (8) So-called flint glass bottles. The Federation shall consist of employers and employees, together with independent members representing science, engineering, finance, and Government Departments, at the earliest possible moment to co-operate with and advise the Government Departments appointed to supervise and promote the glass industry, and that this Federation should eventually take the place of the Temporary Interim Industrial Reconstruction Committee for the glass industry.

5. It is resolved that a copy of the foregoing resolutions be forwarded by the secretary to the Government Departments concerned.

Mr. Jenkinson, in moving the resolutions, stated that, in his opinion, industry must have its own councils, and it must be insisted upon that Tariff Reform and Protection were no longer politics where an industry was concerned. The glass industry must have Government assistance, but at the same time there must not be interference from several Departments. The dye industry, they were told, was to have prohibition for ten years, yet glass was a requisite in the dye industry, as it was in a multitude of industries, which, therefore, should have protection as well. Finally, the speaker appealed for the introduction of efficient plant, to make the industry more attractive to the worker.

Mr. J. Connolly seconded all the resolutions. He laid special emphasis on the fact that the Government Departments mentioned in the first resolutions had justified their continuance by the result shown. The industry must reform itself. After quoting Board of Trade figures, showing that in pre-war days, British wages in the glass trade showed, on an average, a 2 to 1 ratio to those paid in enemy countries, the speaker went on to say that given adequate safeguards, what had been done in the stress and weariness of war could certainly be improved upon later.

Mr. E. J. P. Benn, from the Ministry of Reconstruction, said that he agreed with much that had been stated. In the future, the industries of this country would be in closer touch with Government Departments. A Government Department must seek advice, and it so seldom succeeded in getting hold of the right body. If it acted on the advice of one portion of a trade, it at once found other interests rising, and demanding why they had not been consulted. No Government Department, as such, could have a considered mind on any trade, so that each trade must constitute an independent body of its own to advise the Government Department, hence the formation of Interim Committees. He thought the proposed Federation of resolution 4 would be very much on the lines of the Interim Industrial Reconstruction Committee already established.

Mr. J. E. Foxon, president of the National Federation of Glass Bottle Workers, supported the resolutions in their entirety. He appealed for better conditions for the workman, and supported the formation of Works Committees. He stated that such committees had been compulsory in German works since 1916, and that the expense of them was borne by the masters.

Mr. W. Butterworth opposed the resolutions, and stated that in Germany wages and conditions were as good as in this country. He did not agree with the offering of compliments to Government Departments, and felt that the whole question under discussion was outside the society's scope. It was a calling-up of science in support of political nostrums. The industry, in the past, had suffered from two long-standing effects, namely, the lethargy and lack of enterprise of the manufacturer, coupled with the conservatism and short-sightedness of the worker. The great need of the industry was technical equipment. The imposition of tariffs would only bring retribution. The society, he thought, would be well advised to keep on the lines of technical education and research.

Mr. Redfern moved an amendment to the first resolution, limiting its scope to the development of the research side of the industry only. He also wished to amend the second resolution by defining the key industries, whilst the third amendment was to cut out resolution 4 altogether.

Mr. W. J. Rees considered all the resolutions *ultra vires*, and that they should be dropped. In his opinion, they would do more harm than good, and might be the cause of friction.

Mr. C. J. Peddle supported the resolutions. He appealed for an even closer co-operation of science with the industry which in pre-war days was practically a closed door to the scientist. Yet it did not stave off retribution in the shape of the war. The speaker agreed with Mr. Foxon that the resolution dealing with federation was the most important of all. Such a federation would mean real representation of every shade of opinion in the industry which the Interim Committee did not give. It was certain that many people interested in the industry were unaware of the meeting convened to form the committee, and so could not be represented. The federation aimed at that internal reform emphasised by Mr. Redfern, and, in fact, would depend upon it for existence.

Mr. F. Swann supported the resolutions, and, as a representative of the labour interest, endorsed all that Mr. Foxon had said. In his opinion, the matter was quite within the scope of the Society, in fact, if it were ruled outside, the workmen had no use for the Society. He appealed for better conditions for the workman, and for a better understanding between employer and employee.

All the resolutions were carried, the amendments of Mr. Redfern receiving little support. Two papers, as under, which were down for discussion, were taken as read, and will appear in the Proceedings of the Society.

1. "*The Behaviour of Different Types of Foreign Chemical Glassware Towards Corroding Agents*," by J. W. Canwood, M.Sc., and W. E. S. Turner, D.Sc.

2. "*A Simple Device for Rapidly and Accurately Calibrating Pipettes*," by S. English, M.Sc.

MARINE ENGINEERING AND SHIP-BUILDING AFTER THE WAR.

THE Shipping and Shipbuilding Departmental Committee appointed by the Board of Trade to advise the Government on after-war policy reviews marine engineering and shipbuilding in their second report. This report is signed by Sir Alfred Booth (chairman) Mr. W. S. Abell, Mr. James Brown, Sir G. S. Clark, Sir Archibald Denny, Mr. Edward Hain, Mr. H. D. Hooper, Sir Summers Hunter, Mr. James Readhead, and Mr. Oswald Sanderson. Mr. E. H. Marker acted as secretary and Mr. C. K. Hobson as assistant secretary. The report is dated July, 1917, and was published with the complete report on June 21, 1918.

Production.—The report repeats a complaint made by other committees that we have no really comparative statistics of production. Some valuable new particulars were collected by the committee and obtained from Lloyds. The ship and engine branches as a whole employ :—

	£
Capital	35,000,000
Employees	200,000
Annual value produced	50,000,000

These figures do not include Admiralty dockyards or the small but growing plants in the Dominions. The firms often build vessels in advance of orders and deliver vessels on credit up to five yearly payments. About one-fifth of the construction is for foreign owners. It is very rarely that British owners order ships from foreign sources. The plant is generally first-rate. The production is always growing, though there are periods of depression, 1907–8 being years of severe depression. The production for over twenty years, and its proportion to the world production are as follow :—

Average Annual Production of Ships.

	Tons.	Per Cent.
1892–4	998,000	81·6
1895–9	1,170,000	72·8
1900–4	1,358,000	59·9
1905–9	1,396,000	61·0
1910–14	1,660,000	61·9

In addition, the Dominions built an annual average of 10,000 tons in 1892–4, increasing to 35,000 tons in 1910–14. The figures show a steady absolute increase and a relative fall; but up to 1913 we still built over half the world production.

After the war increased production may be expected in the United States, Italy, Holland, and Scandinavia. Japan is now building in excess of her own needs and is a seller of ships. For a time all yards will be busy after the war, but later there may be severe competition.

The following are usually delivered to the industries as completely finished products: Windlasses, winches, pumps, steering gears, electric generating plant, refrigerating machinery, and fittings such as brass and electroplate furnishings, nautical instruments, cabin furniture and upholstery, lubricators, indicators, gauges, cocks and valves.

Annual Consumption of Steel.—The following table gives particulars of the consumption of steel in 1913 :—

	Tons.
Total British production of steel ingots	7,663,000
Total British consumption (allowing for exports and imports) ...	6,325,000
Total British consumption of ingots in new ships	1,850,000
Total British consumption of steel in new ships (*i.e.*, ingots less working, cutting, machining, &c.)	1,400,000
Total British consumption of steel on ship repair work ...	... (not known)

These figures show that 29 per cent. of the total British consumption of steel was used in ship and marine engine construction. Iron is also used very largely in engine construction, but no similar figures are available separately for marine work.

Steel plates and sections—	Tons.	Value. £
1912	952,000	6,553,000
1913	896,000	6,766,000

The figures show a considerable rise in the average price: from 6*l.* 17*s.* 8*d.* per ton in 1912 to 7*l.* 11*s.* per ton in 1913, though the quantity used had fallen nearly 5 per cent.

Foreign Materials.—A considerable and increasing quantity came from abroad, mainly from Germany and partly from Austria. From these countries the rough machined forgings and finished crankshafts were "dumped" with the political object of putting our forges out of action and reducing our powers of producing guns and war material. This is the considered opinion of the committee, and it should be noted that the enemy objective was not competition in the articles sent here, but the crippling of the huge forging and casting plants in order to hamper the production of other articles. This effect was produced—"forges equal if not superior to anything in Germany," as well as good plants of less than the highest efficiency, were unable to continue in action. During the war this loss has been made good.

The report discusses the points about inferior plant in detail, but the main outcome is that continued fresh expenditure on plants became unprofitable. In the import and export statistics the marine supplies are not distinguished from other steel sections, forgings, castings, &c. The appended figures refer to marine work only and are made up from the account books of the engineering firms.

The proportions cannot, of course, be traced generally, but information about the large special forms was carefully collected. The imported pieces used amounted to the following percentages (based on weight) of the total pieces used :—

	1912.	1913.
Stems, stern frames, rudders, rudder parts, propeller brackets—		
Forgings, steel	5·0	4·5
Forgings, iron	0·8	0·2
Castings, steel	21·5	22·6
Shafts: thrust, intermediate and propeller—		
Forgings, steel	43·6	42·7
Forgings, iron	1·3	3·0
Other engine parts—		
Forgings, steel	10·6	14·3
Forgings, iron	—	—
Castings, steel	5·2	0·9

Practically all came from Germany, a little from Austria. About 7 per cent. of the steel shaft forgings and 1 per cent. to 2 per cent. of the engine steel forgings came from Denmark. All these percentages went into merchant ships, as the Admiralty usually specify British materials. The figures do not include Admiralty dockyard work.

British Forgings and Castings.—For the same classes of forgings and castings as in the previous table the weights (in tons) of home-made are given for both mercantile and Admiralty work done by private firms, but excluding Admiralty dockyard work :—

1913.	Mercantile. Tons.	Admiralty. Tons.
Stems, &c.—		
Steel forgings	1,172	1,024
Iron forgings	5,295	51
Steel castings	1,306	1,625
Shafts—		
Steel forgings	10,929	8,049
Iron forgings	1,386	50
Engine—		
Steel forgings	2,721	3,316
Iron forgings	1,568	97
Steel castings	2,493	877
Total	26,870	15,089

These are the forged (not machined) weights in all cases. The value of the mercantile items is over 720,000*l.*, or 27*l.* per ton average. The value of the Admiralty work is not given.

The following figures give an indication of the development of this class of British work during the war, the 1917 figures being estimated production :—

Marine.	1913. Tons.	1917. Tons.
Steel forgings	27,211	89,352
Iron forgings	8,447	9,246
Steel castings	6,928	7,350

German and British Prices.—A table of comparative prices at eight dates ranging from January, 1905, to December, 1913, is given for turned shafts. For finished crankshafts German prices were from 21 per cent. to 28 per cent. lower than British, except on three dates, when they were 8 per cent., 4 per cent. and 16 per cent. lower. Rough turned straight shafts (propeller shaft pieces) of 12 in. diameter and upwards were 18 per cent. to 36 per cent. lower; from 1908 they were never less than 27 per cent. lower.

Steel plates were quoted on fairly equal terms in

1911. The German prices were lower in 1912, but less than 5 per cent. lower. In 1913 and up to July, 1914, they were very much lower. The average prices for the three and a-half years period were: German, 6*l.* 6*s.*, per ton; Scottish, 6*l.* 18*s.* 9*d.* per ton—both net delivered Clyde.

Angles, bars, boiler plates, sheets, slabs, shafting, &c., in 1914 were generally 30 per cent. cheaper, the differences per cent. varying from 23 and 24 to 41 and 46 on different items.

Recommendations.—The committee is generally in agreement with the other engineering committees on questions such as "dumping," depreciation, combination amongst employers, consular service reform, extension of banking facilities, patent law reform and opposition to the adoption of the metric system. A similar agreement exists about apprenticeships and technical education, but this Committee favours raising the school leaving age to 16, and claims for the boys not only the teaching of a trade, but the wider education required to produce a good citizen.

On the tariff question the committee is at variance with the materials and machinery committees. It strongly insists that materials—steel and others—must be bought in the best market and declines to recommend a duty on imported materials. It disfavours bounties and general tariffs with special drawbacks. While willing to consider "specific proposals" from the other committees, this committee concludes by stating plainly that it is unable to recommend the adoption of "any policy in regard to materials for shipbuilding and marine engineering other than one which will secure their free admission into this country in the future as in the past." They, however, make an exception in favour of anti-dumping legislation similar to the United States and Canadian measures.

The third part of the report, which deals with shipping, develops the argument further against Protection. The main bearing of it is that the British ship has to com ete on the open seas against ships built in all countries, and that it must be without handicap as to cost of construction, cost of running, &c.

JAPANESE SHIPBUILDING.—We read in *The London and China Telegraph* that Mr. Uyemura Shumpei, Mr. Shimidzu Gendatsu, and half a dozen other Osaka business men have taken in hand the establishment of a dock company at Minami Fukusaki-cho, at the mouth of the Shirinashi River, Osaka. The proposed company will have a capital of 1,000,000 yen, and will be named the Osaka Dock Company. It will be engaged in building or repairing ships.

A REVIEW OF THE FOREIGN TECHNICAL PRESS.—One of the tasks of the General Staff at the War Office during the war has been the issue of a daily review of the Foreign Press, the scope of which has been extended from time to time by the preparation of supplements dealing with special subjects. A fortnightly Technical Supplement, compiled with the co-operation of the Institution of Civil Engineers, was added to the list in January last, and since then has been widely circulated through official channels, for the assistance of naval and military workers. This limitation has now been removed by the decision to place the Technical Supplement on sale, and the issues of May 28 and subsequent numbers may be obtained at the cost of 6*d.*, through any bookseller, or directly from His Majesty's Stationery Office, at Imperial House, Kingsway, London, W.C.2.

HIRE OF RAILWAY WAGONS.—It has recently come to the notice of the Minister of Munitions that in many cases unreasonable rates of hire are being demanded for privately-owned railway wagons. The Minister, therefore, has decided that in the administration of the Order of December 29, 1916, made by him under the Defence of the Realm Regulations controlling second-hand railway material, no permits for hiring will be granted at rates exceeding the following: 12-ton wagon, 8*s.* 3*d.* per week; 10-ton wagon, 7*s.* 3*d.* per week; 8-ton wagon, 6*s.* 6*d.* per week—these rates to include the keeping of the wagon in repair by the lessor. The rates are applicable only to wagons in such a state of repair and of such design that they will be passed by the railway companies for main line traffic and for carrying the loads stated. The maximum rates will be allowed only for wagons of the best type for any specific class of traffic. Hiring agreements will be limited to the duration of the war and six months afterwards. All applications for sanction to hiring agreements at present awaiting decision will be dealt with on the above basis, and notification will be duly made to those concerned by the Railway Materials Licences Department, Ministry of Munitions, Whitehall Place, S.W. 1, the Department of the Ministry responsible for the administration of the above-mentioned Order. About 700,000 privately-owned railway wagons will be affected by the new Order. At present there is no community in the ownership of these wagons, and as a result: (*a*) Government departments have frequently found it difficult to obtain sufficient wagons for the transport of war material. (*b*) The coal, iron and steel trades have been particularly affected. The organisation of carriage of war material, of partly finished articles and of the completed products from factory to quayside has been difficult. (*c*) As a consequence rates of hire have risen to an excessive degree. Whereas at the outbreak of war the price of hire (with responsibility for repairs) seldom exceeded 3*s.* 6*d.* per week for a 10-ton wagon, rates of 10*s.* to 12*s*, are now being paid, and as much as 15*s.* and 20*s.* has been asked. It is in these circumstances that the Minister of Munitions has interposed by limiting the rates of hire. At the same time steps have been taken to prevent excessive speculation in second-hand wagons.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.he

Scotch Steel Trade.—Intense activity prevails in t is steel works and everything points to a continuance of th for many months to come. Meantime the chief demand is for shell bars, plates and sections for the shipbuilding yards and general engineering, the material required for the construction of locomotives—a very heavy item—and channels and joists for structural business. These demands practically absorb the entire production of steel in the West of Scotland. As the output of steel of high tensile quality has rather fallen off lately, discard bars are not so plentiful as they were. While all the steel produced is being required for work of national importance only a limited quantity is available for export to France and Italy. A largely increased output may be anticipated shortly.

Malleable Iron Trade.—The pressure for delivery of malleable iron is unabated, even with every mill employed to its fullest capacity, and both in the iron and the steel departments the demand for material is very heavy. Orders are in excess of even what they were, those on general account, however, receive but scant consideration—work of national importance comes first. In a few instances orders for sectional material for mining and agricultural work are being undertaken, but this is almost in the nature of a special privilege. Some deliveries of light rails on French account represent the export trade at the moment.

Scotch Pig-Iron Trade.—In the pig-iron trade supply still falls short of demand, nor is it possible under existing circumstances for producers to avoid this, the increasing shortage of labour being mainly responsible. The steel works absorb the entire production of hematite and none, therefore, is available for general consumers. There is a marked scarcity of other brands also, notably of foundry iron.

Another Shipbuilding Record.—Following the announcement last week of Messrs. Harland and Wolff's achievement, it seems evident by the latest information that there is every prospect of still better results being attained. Another 8,000-ton oil-carrying vessel has now been plated in 9 weeks, a part of the construction which, on the sister ships immediately preceding, took from 10 to 16 weeks.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—Conditions in the steel trade continue to be on the easy side. There is scarcely a single department in which there has not been an appreciable decline in activity, different sections being affected in various degrees. Business is fairly active at the open-hearth furnaces, but the output is nothing nearly so big as it has been. Orders for crucible steel are fitful, and although there has been an increase in the demand for alloy steel, actual production has not benefitted as there are ample supplies in stock. Generally speaking, all departments are producing less than they could do, and it is not surprising that the comparative slackness which has been occasioned has led to new pressure on the Government to reconsider the shipping restrictions with a view to permitting ampler export facilities for commercial business. The supply of scrap has undergone no change.

South Yorkshire Coal.—Supplies generally, are on the short side, and business continues to be dominated by contract requirements. Best steams are going away as quickly as they can be produced, there being a big demand for all classes of home consumers. Export requirements, too, are considerable. There is no slackening in the demand for cobbles, nuts and slacks. The position in the house coal section continues very difficult. Supplies are coming forward very slowly, and order books are heavily in arrears. All classes of coke are difficult to obtain, and maximum prices rule. Quotations:—Best branch hand-picked, 23*s.* to 24*s.*; Barnsley best Silkstone, 23*s.* to 23*s.* 6*d.*; Derbyshire best brights, 21*s.* to 22*s.*; Derbyshire house coal, 18*s.* 6*d.* to 19*s.* 6*d.*; best large nuts, 18*s.* 6*d.* to 19*s.* 6*d.*; small nuts, 17*s.* 6*d.* to 18*s.* 6*d.*; Yorkshire hards, 18*s.* 6*d.* to 19*s.* 6*d.*; Derbyshire hards, 17*s.* 9*d.* to 18*s.* 9*d.*; best slacks, 14*s.* to 14*s.* 6*d.*; seconds, 13*s.* to 13*s.* 6*d.*; smalls, 9*s.* to 10*s.*

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—Business in Cleveland pig-iron is only quiet, but renewal of activity is assured with the issue of July allocations of foundry quality to home consumers. This month's deliveries are very heavy, facilities for railing parcels having greatly improved. With the Tyneside foundries idle this week for the recognised annual holiday, deliveries to that district have shrunk, though some supplies are going forward to the Tyne to be available on the resumption of work next week. Customers in Scotland and in the Midlands are eagerly taking up any iron that can be arranged for. Forge quality is in only moderate request and is fairly plentiful, some of the makers, as well as consumers, having stocks. Export trade is governed by the tonnage question. As more vessels have been and are still coming to hand, June returns promise to show substantial loadings. For home consumption, No. 3 Cleveland pig-iron, No. 4 foundry and No. 4 forge are all quoted 95*s.*, and No. 1 is 99*s.*; and for shipment to France and Italy, No. 3 and the lower qualities are 114*s.*, and No. 1 is 119*s.*

Hematite Iron.—There is considerable activity in hematite iron both on home and foreign account. The better supply of trucks permits more liberal supply to home customers, and shipments are larger. Continued extensive use of basic iron and scrap for the manufacture of steel assists very materially to strengthen the situation; and on the whole the hematite branch may be described as in a healthy state, though output is absorbed as fast as it is produced. Distribution continues to be carefully controlled. Nos. 1, 2 and 3 East Coast brands are 122*s.* 6*d.* for home consumption and 147*s.* 6*d.* for export to France and Italy.

Blast Furnaces in Operation.—The number of blast furnaces at present in operation in this district is 75, of which 33 are producing Cleveland pig-iron, 22 are making hematite, and 20 are manufacturing other kinds of iron.

Manufactured Iron and Steel.—Demand for finished iron and steel continues very heavy. It is gratifying to have the assurance that not only are the enormous requirements of the shipyards receiving satisfactory attention, but that manufacturers of material for shipbuilders are in a position to deal adequately with even increased demand. Firms are so much engaged on work of national importance that little opportunity is afforded for ordinary commercial transactions. Prices are very stiff. The following are among the principal market quotations to home customers:—Common iron bars, 13*l.* 17*s.* 6*d.*; best bars, 14*l.* 5*s.*; double best bars, 14*l.* 12*s.* 6*d.*; iron ship plates, 15*l.* 10*s.*; iron ship angles, 13*l.* 17*s.* 6*d.*; steel ship plates, 11*l.* 10*s.*; steel ship angles, 11*l.* 2*s.* 6*d.*; steel boiler plates, 12*l.* 10*s.*; steel hoops, 17*l.* 10*s.*; and heavy steel rails, 10*l.* 17*s.* 6*d.* Whilst quotations for export are not fixed, they may be given approximately at 2*l.* to 3*l.* above home prices.

Coke.—Business in coke is quiet, due to great scarcity of supply. Demand on behalf of neutrals is heavy, but there is scarcely any to spare for such business, and exporting to neutrals is practically at a standstill. Home and allied needs absorb the output. Disappointment is expressed that no reference was made to coke prices in the recent Board of Trade Order advancing quotations for coal. Both makers and merchants declare that the situation justifies higher prices. Though the position is causing some anxiety, it is hoped and believed that absolute needs of home consumers will be adequately dealt with. Average blast-furnace coke is 33*s.* at the ovens, and quality low in phosphorus 35*s.* 6*d.* at the ovens.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Local Markets.—The position on the markets has not undergone any material change during the past week. The best steam collieries are pretty fully stemmed, but drys are less favourably placed and sto ks are accumulating. Smalls, however, continue to be the weakest spot on the market. The best bunker descriptions are well booked, but the lower grades are rather plentiful. Here and there shippers are instructed to load 25 per cent. smalls, but this practice is not yet general enough to secure the automatic absorption of the normal output of small coals. In the general arrangement of business much is expected from the new committee which has been set up. Under the conditions which have hitherto prevailed, the distribution of business under the control of the authorities was not in every instance satisfactory, and it is hoped there will be an improvement in this respect. Pitwood supplies are well maintained. Iron ore cargoes are also arriving regularly, but coke supplies are relatively scarce. Following the order of the Board of Trade which became operative on Monday, the new schedule prices are as follow:—Steam: Smokeless best, 38*s.*; second quality, 36*s.* 6*d.*; seconds, 35*s.* 9*d.*; ordinaries, 35*s.*; best drys, 35*s.*; ordinary drys, 33*s.* 6*d.*; steam smalls (No. 1) 26*s.* 6*d.*, (No. 2) 26*s.*, No. 3) 25*s.* 6*d.*, (No. 4) 25*s.*, (No. 5) 24*s.* 6*d.*, (No. 6) 24*s.*, (No. 7) 23*s.* 6*d.*, (No. 8) 23*s.*; washed smalls, 27*s.* 6*d.*; best Black Vein, large, 35*s.*; ordinary Western Valley, 34*s.*; best Eastern Valleys, 34*s.*; second Eastern Valleys, 33*s.*; best washed nuts, 35*s.*; seconds, 33*s.* 6*d.*; best washed peas and beans, 32*s.* 6*d.*; seconds, 31*s.* 6*d.*; unwashed duff, (1st quality) 23*s.*, (2nd quality) 21*s.*, (3rd quality) 19*s.* Bituminous: Best households, 38*s.*; good households, 35*s.* 9*d.*; No. 3 Rhondda large, 35*s.* 9*d.*; smalls, 31*s.*; No. 2 Rhondda large, 32*s.*; No. 2 Rhondda through, 28*s.* 6*d.*; ditto and other Through (seconds), 27*s.*; No. 2 Rhondda smalls (best), 24*s.*; No. 2 Rhondda smalls (seconds), 22*s.*; gas through, 30*s.*; gas smalls, 26*s.*

Newport.—The position in regard to Monmouthshire coals is not so favourable this week. Though the collieries are kept working, the shortage is not nearly so acute as was recently the case notwithstanding reduced outputs. For inland consumption, however, the demand is very strong, and distribution continues under the direction of the Coal and Coke Supplies Committee. The new schedule prices are as follow:—Steam: Best Black Vein, large, 35*s.*; ordinary Western Valley, 34*s.*; best Eastern Valleys, 34*s.*; second Eastern Valleys, 33*s.* Bituminous: Best households, 38*s.*; good households, 35*s.* 9*d.* Miscellaneous: Patent fuel, 35*s.*; coke-oven coke, 52*s.* 6*d.*; pitwood, 65*s.*

The Anthracite Area.—The following are the prices under the new schedule which came into operation on Monday:—Best breaking, large, 35*s.*; second breaking, large, 34*s.*; third breaking, large, 32*s.* 6*d.*; Red Vein, large, 30*s.* 6*d.*; machine-made cobbles (best) 47*s.* 6*d.*, (seconds) 46*s.*, (thirds) 44*s.*; Red Vein cobbles, 41*s.*; machine-broken nuts (French, Paris and stove), (best) 47*s.* 6*d.*, (seconds) 46*s.*, (thirds) 44*s.* 9*d.*; Red Vein nuts, 41*s.*

THE WORLD'S LARGEST SHIPYARD AT HOG ISLAND ON THE DELAWARE RIVER, PHILADELPHIA.

(*For Description, see Page* 731.)

FIG. 1. VIRGIN LAND AT HOG ISLAND ON SEPTEMBER, 20, 1917.

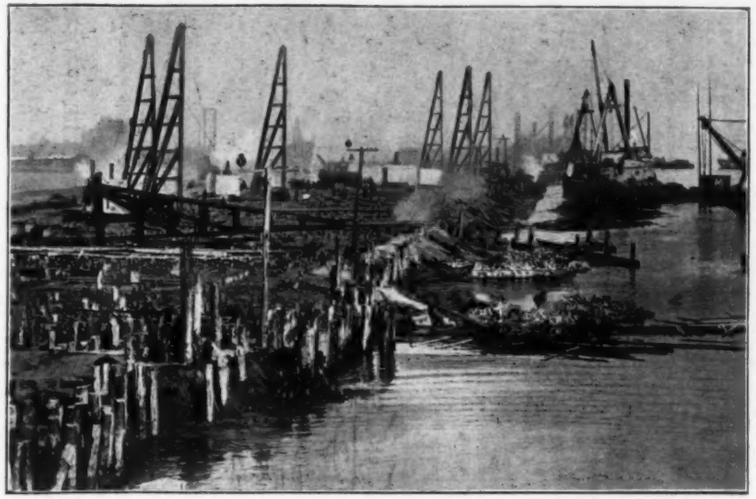


FIG. 2. SLIPWAY GROUP NO. 1; TWELVE WEEKS FROM COMMENCEMENT.

FIG. 3. THE TWENTY-FIRST SLIPWAY THIRTY-ONE WEEKS AFTER THE YARD WAS COMMENCED.

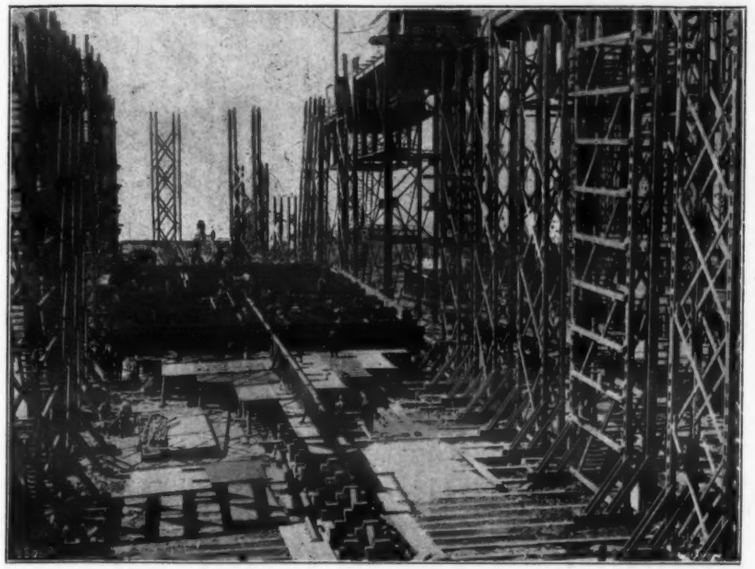


FIG 4. THE TWENTY-FIRST SLIPWAY FOUR WEEKS LATER; A HULL WELL UNDER CONSTRUCTION.

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The charge for advertisements is three shillings for the first four lines or under, and eightpence for each additional line. The line averages seven words. Payment must accompany all orders for single advertisements, otherwise their insertion cannot be guaranteed. Terms for displayed advertisements on the wrapper and on the inside pages may be obtained on application. The pages are 12 in. deep and 9 in. wide, divisible into four columns of 2¼ in. in width. Serial advertisements will be inserted with all practicable regularity, but absolute regularity cannot be guaranteed.

Advertisements intended for insertion in the current week's issue must be delivered not later than 5 p.m. on Thursday. In consequence of the necessity for going to press early with a portion of the edition, alterations for standing advertisements should be received not later than Monday morning.

SUBSCRIPTIONS, HOME AND FOREIGN.

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All accounts are payable to "ENGINEERING," LIMITED. Cheques should be crossed "Union of London and Smith's Bank, Limited, Charing Cross Branch." Post-Office Orders should be made payable at Bedford-street, Strand, W.C. 2.

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We desire to call the attention of our readers to the fact that the above is our SOLE ADDRESS, and that no connection exists between this Journal and any other publications bearing somewhat similar titles.

TELEGRAPHIC ADDRESS } "ENGINEERING," WESTRAND, LONDON.
TELEPHONE NUMBERS—3683 and 8598 GERRARD.

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With a Two-Page Plate of the BASCULE BRIDGE OVER THE TROLLHÄTTA CANAL AT VANERSBORG.

NOTICE.

Owing to the recent Government restrictions, and to the enormous increase in the price of paper occasioned thereby, the Proprietors of "ENGINEERING" are compelled to advance the price of this Journal further from 8d. to 9d. per copy. This increase dates from and includes the issue of Friday, March 1, 1918. The change will not apply to unexpired subscriptions. The revised rates for new subscriptions are given in the adjoining column.

NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions now imposed by the Government on the importation of paper and the consequent shortage of supplies, Newsagents after June 24th will not have copies for chance customers, therefore readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk.

ENGINEERING.

FRIDAY, JUNE 28, 1918.

FOUR-CYCLE *versus* TWO-CYCLE DIESEL ENGINES.

THERE is no problem connected with internal-combustion engines that has absorbed so much attention, and to which such a large amount of discussion has been given, as that of the relative merits of the four-cycle and the two-cycle principles. This is true in general for all types of internal-combustion engines, but where the Diesel engine is concerned the question is still more potent in that the Diesel principle lends itself well to units of comparatively large power on account of the fact that the fuel is only introduced into the cylinder at the moment of ignition. Thus for a given size of cylinder the heat stresses are, if anything, less with a Diesel engine than with a gas engine.

The larger the power, it is generally admitted, the better the case for the two-cycle principle, because of: 1. The limiting size of the exhaust valve of four-cycle engines for satisfactory working; 2. The better turning moment with two-cycle engines; 3. The smaller cylinder required with two-cycle engines to develop equal power in the same number of cylinders, although at a higher consumption of fuel per unit power developed.

Furthermore, the Diesel principle removes some of the most severe objections to the two-cycle principle. The scavenging with Diesel engines is carried out by air and air alone, instead of a mixture of air and gas, so that the danger of ignition of the incoming gas, or of the loss through the exhaust ports of part of the charge does not arise with the Diesel engine. The foregoing are the points around which general discussion has centred. In the following, attention is confined solely to the Diesel engine.

The practice hitherto of makers of Diesel engines is varied. Some few have stuck firmly to the two-cycle throughout a large range of power, others have confined themselves exclusively to the four-cycle, whereas a few of the largest manufacturers build four-cycle engines up to a maximum of some 200 to 250 b.h.p. per cylinder, and construct only two-cycle engines above that power per unit, on the assumption that the higher the cylinder power the greater the attractiveness of the two-cycle engine. Moreover, for special work, where lightness and compactness are of the highest importance, such as for submarine work, the two-cycle engine has been credited with a greater capacity for fulfilling these requirements than the four-cycle engine, and theoretically, looking superficially at the subject, double the number of impulses achieved by the two-cycle principle should have justified this choice.

To attempt to conclude from the results of two- and four-cycle practice up to the present time without having reliable knowledge of all the facts, would simply open the way to a lengthy and probably useless controversy. It may be stated, however, that the two-cycle engine has not gained ground, in fact, the four-cycle if anything, even for higher and higher powers, is increasing in application and the claims to compactness and lightness of the two-cycle engine have not fully been substantiated by the results of actual practice.

It is not desired to forecast the distant future. It is sufficient to move in small steps, especially in internal combustion-work, and as throwing a certain light on the subject outlined herein. Messrs. Franco Tosi, of Milan, Italy, with commendable enterprise, have recently built two similar engines, one a two-cycle and one a four-cycle, which they have tested one against the other with a view to comprehensive comparison, and the results of these experiments deserve special attention.

In order that those tests may be regarded as comparative, the underlying principles of the two designs must be examined for sufficient similarity as a basis. From the drawings, which we hope to publish later, both show the same trend in design. Both are of the totally-enclosed, high-speed, forced-lubricated, trunk-position type of engine. The designed speed of revolution, and the method of carrying the main tension stresses are exactly the same in both cases, and the cylinder dimensions only vary slightly. The two-cycle engine has the six working cylinders in the centre with a scavenging pump and a compressor at each end. The four-cycle engine has eight working cylinders with two compressors at the forward end as against the six working cylinders of the two-cycle engine. There are, naturally, a number of differences, apart from the main arrangement, required by the cycle of operation adopted, such as the cooling system of the two-cycle pistons and the scavenging valve gear, and with the four-cycle the valve gear and cylinder head for accommodating the various valves.

The next important point to which attention must be directed is the designed power of these engines, which is the same for both, i.e., 1,300 b.h.p., and which equals about 215 b.h.p. per cylinder, with the two-cycle and 160 b.h.p. per cylinder with the four-cycle engine. This size was chosen because the two-cycle engine is a standard submarine engine of the makers, and it is to be noted in this connection that Messrs. Tosi are experienced designers of both two- and four-cycle Diesel engines. It might be urged that this size is not the best for a suitable comparison. If a lower power had been chosen then a great advantage might have lain with the four-cycle, certainly not conversely; but, on the other hand, if a larger size had been the subject of experiment it might be contended that the position—later to be exactly given—might have been reversed in favour of the two-cycle. There is the fact that with the four-cycle engine, two exhaust valves were accommodated in each cylinder head, and as has already been stated, it has been found in practice that under certain conditions the question of the exhaust valve has been a limiting factor in respect of the probable power output from a given cylinder and for a desirable reliability of continuous operation in practice. With this four-cycle engine, each cylinder has two inlet and two exhaust valves, and the exhaust valves are water cooled, not only in the cages, but also the valves themselves. This remains an outstanding point, although it must be conceded that 210 b.h.p. per cylinder for a two-cycle and 180 b.h.p. per cylinder for a four-cycle engine are no mean outputs, especially for the high-speed type of engine.

It remains to discuss the actual results, and to draw deductions therefrom. Lengthy tests were carried out, 145 hours continuous non-stop runs being made, and both engines developed their designed power of 1,300 b.h.p. at 300 r.p.m. It was found, however, that the two-cycle engine was not capable of developing higher than this figure, whereas the four-cycle engine at the same speed of revolution, 300 r.p.m., gave 1,450 b.h.p., and as a maximum power at higher revolutions developed 1,585 b.h.p. for a short period. As regards fuel and lubricating oil consumptions the advantage lies greatly in favour of the four-cycle engine. At full load, the four-cycle figure was 0·41 lb. of fuel, and lubricating oil per b.h.p. hour, whereas the two-cycle consumption was 0·573 lb. per b.h.p. hour. Fuel consumption tests were carried out at various powers and the advantage in this respect of the four-cycle at full power was well maintained at lesser powers.

In regard to flexibility, the four-cycle showed marked superiority. With the two-cycle engine at

300 r.p.m., the compression was 460 lbs. per sq. inch, whereas at 120 r.p.m., the compression fell to 315 lbs. per sq. inch, at which pressure the temperature generated would be insufficient to support combustion of heavy fuel oil, and so the engine would stop. With the four-cycle engine at 300 r.p.m., the compression pressure was 490 lbs. per sq. inch, and at 100 r.p.m., had only fallen to 445 lbs. per sq. inch.

The reasons for a fall in compression with a decrease in the speed of revolution are as follow:—1. Decreased revolutions are almost always accompanied by a diminution of power output, which means less fuel consumed, making for a cooler cylinder, and so less heat to be taken up by the induction air, and so a lower final compression pressure. 2. The compression leakage per cent. past the main tube rings is a function of the size of cylinder and of time. The smaller the time of compression, the less the leakage, so that when running at slow speeds the compression is lowered due to this cause. 3. Again, with slow running, the time element allows more heat to pass to the cylinder jacket, further reducing the pressure and temperature of final compression. These three causes are common to both two- and four cycle engines. With two-cycle engines, the reason for the compression pressure dropping much more rapidly with reduced revolutions than with the four-cycle engine is on account of the scavenging air pressure.

The slower the speed of running the lower the pressure of the scavenging air, because of the lesser resistance against which the scavenging pump is required to deliver. In the working cylinder, where less fuel is being burnt, there are less gases to be expelled. Further, the time element enters into the question of leakage of scavenging air through the exhaust ports, so that, whereas at 300 r.p.m., the scavenging air pressure may be as high as from 5 to 6 lbs. per sq. inch at 120 r.p.m., it would be as low as 1·5 to 2·5 lbs. per sq. inch, and the scavenging air pressure is that at which compression begins, and the final compression pressure falls in direct proportion on this account alone. On the other hand, with four-cycle engines, the pressure at which compression begins is substantially the same, irrespective of the speed of revolutions. This experiment further showed that the noise of running of the two-cycle engine was very much more than with the four-cycle, due to the suction of the scavenging pumps and the high speed of the valve gear. With two-cycle engines, the valve gear operates at engine speed, and with four-cycle engines at half-engine speed.

Messrs. Franco Tosi have decided, in future, to abandon the two-cycle principle, and to confine themselves to the four-cycle for reasons substantially as stated, which may finally be recapitulated:—1. Elimination of the scavenging air pumps with their receivers, diminishing thus the size of the engine and decreasing the noise. The four-cycle engine of equal power is, approximately, the same size and of the same weight as the two-cycle. 2. Lesser amount of heat units abstracted by the cooling water and the four-cycle engine contributing to the lower-fuel consumption with the four-cycle engine. 3. The inefficiency of scavenging with two-cycle engines, as compared with the four-cycle. 4. The possibility of using higher piston speeds with the four-cycle engine. 5. Greater flexibility of the four-cycle engine. 6. Simpler mechanical parts of the four-cycle engine. 7. The fuel pumps and valve gear of the four-cycle engine only ran at half-engine speed, making thus for easy running conditions.

ROAD MAINTENANCE.

THE highway question promises to prove one of the most difficult with which the nation will have to deal after the war. Up till the fateful summer of 1914 substantial progress was being made in road betterment and reconstruction under the auspices of the Road Board, but the revenue received by that body from the petrol tax has been of necessity diverted to other ends. Moreover, three-fourths of our road rollers have been commandeered for military purposes. Materials and labour have at the same time been scarce and dear, and as a natural result the road maintenance has fallen much below the normal standard. Some interesting particulars as to these increased costs were given in a paper on rural roads read by Mr. J. A. Webb before the Institution of Municipal and County Engineers at their meeting in London last week, and from this we extract the following table:—

Comparative Costs, &c., between Time.	*Pre-War* s.	d.	*and Present* s.	d.
Cost of granite per ton, carriage paid	12	6	18	6
Cost of flints per ton, carriage paid	5	0	6 to 7	6 6
Average cost per mile carting per ton	1	0	1 to 2	9 0
Horse, cart and man per day	6	0	12	6
Two horses, cart and man per day	10	0	18	6
Surface tarring, per superficial yard	0 to 0	1 1½	0 to 0	2½ 3
Roadmen's wages, per day	2 to 3	8 0	5 to 5	0 4
Number of roadmen employed	700		300	
Steam rollers at work ...	14		7	
District surveyors (12 Main road districts)	12		8	

In view of the scarcity of labour many road authorities have, it appears, had considerable unexpended balances at the end of each year's work. Mr. E. P. Hooley says that in certain cases these unexpended balances have been retained to establish a fund towards the cost of the extensive reparations which will be necessary when normal conditions are restored. In other cases the opportunity has been taken to reduce rates, possibly in the hope that Parliament may then be more ready to provide financial assistance from the Treasury than it would be if it knew that a considerable accumulated surplus was in existence.

No doubt there will be a strong impulse towards the nationalisation of many important roadways, and a much better case can be made out for this than for most other proposals of the same character. Many rural districts have been saddled with the heavy cost of repairing damage done by traffic, conducted in the interests of distant and distinct communities. That our highway authorities are the local authorities has, moreover, been one of the principal difficulties encountered by all schemes for extended road improvement. Short but expensive widenings might in many cases greatly enhance the value of a great main road, or the traffic may demand new and stronger bridges. The advantage of such improvements is reaped by all road users, but the cost would fall heavily on the local authority immediately concerned. Nationalisation has, however, some drawbacks even here. It is true that until the advent of the motor car the 24,000 miles of national roads in France were reckoned the best in the world. Such large and highly centralised organisations are, however, but ill-adapted to meet revolutionary changes in conditions, and it is generally admitted that the road authorities in this country were more successful in dealing with the difficulties which arose at the beginning of this century from the altered character of the traffic. A single central authority is inclined to centralise its "thinking" whereas with us there were many minds independently engaged on the problem. Possibly future conditions may best be met by an extension of the powers and resources of the Road Board assisting but not superseding the local authority.

In the past, farmers have been loud in complaining of the damage done to the highways by motor traffic. It is of interest, therefore, to note that at the meeting already referred to Mr. J. A. Webb stated that the damage done to the roadways by the soil or manure coated wheels of farmers' vehicles is in many districts very serious, and he regretted that the road authorities could not compel the farmer to clean the wheels of his vehicles before passing them on to the road. All speakers seemed to agree that water-bound macadam was proving exceedingly costly. Some surveyors still seem to cling to the belief that a pneumatic tyre exercises a suction on the road crust, a theory which has been proved to be untenable by actual experiment. The damage done is really due to pressure, not suction. When a rapidly-moving pneumatic-tyred vehicle passes over a water-logged surface the water under the wheel tread is put under pressure, and in trying to escape tends to burst up material on both sides of the track.

Very good results are reported from the use of tarred clinker. The clinker from refuse destructors has commonly been regarded in the past as a mere nuisance to be got rid of as inexpensively as possible, but from the reports by surveyors at the meeting it seems to have a distinct value for road-making purposes. Mr. G. Green, M.I.C.E., of Wolverhampton, for example, said he had used it under very trying conditions in that borough. It was first tried for Market-street, a short and narrow roadway, where the wear and tear on the water-bound macadam previously adopted had been excessive. The carriage way here is 20 ft. wide and the clinker Mexphalte was deposited in two layers. The under layer was 3 in. thick and the top coat or carpet 1 in. thick. The cost was 8*s.* 7*d.* per square yard, and the work has, it was stated, proved very successful.

One of the great difficulties met with by our road surveyors has been the poor foundations of most of our highways. Mr. E. P. Hooley, in his contribution to the subject under discussion strongly emphasised this point, declaring that it was useless to expect to obtain a sound permanent road by laying down 3 in. of permanent facing on a sub-base of 4 in. of round pebbles. He suggested that much could be done even under present conditions to prepare roads for permanent surfacing later on. For this, where the bottom is dry, he recommended the use of furnace slag, broken to 3½in. to 4in. gauge. having its voids carefully packed with smaller material and well rolled. This, he stated, formed an almost ideal "subcrust" for receiving a permanent face later on, and in the meantime it would carry ordinary traffic well.

Where the ground was water-logged he advised the use of faggots laid angle-wise and packed with engine ashes. After well rolling this layer a course of engine ashes or furnace clinker, 4 in. thick, filled in with finer material, and thoroughly rolled, would complete the foundation layer. Faggots were also recommended for use in strengthening of the sides of roadways. This Mr. Hooley effects by excavating the undesirable material and filling in first with a 4-in. layer of rolled clinkers, followed by rolled fagotting laid at an angle of 45 deg. with the line of the roadway. This is surmounted by 4 in. of rolled clinker filled in as already explained.

BRITISH AND COLONIAL IRON ORE SUPPLIES.

IMPORTANT developments are under way in the matter of our iron-ore supplies. Shipping difficulties have caused attention to be directed to the question of increasing our home supply, while the quickened interest in Empire resources and the desire to render ourselves more independent of foreign countries, are combining to raise the problem of exploiting certain Colonial reserves of ore. The whole question is of vital importance, for next to coal, iron ore is our most essential industrial raw material.

Roughly, out of 21,000,000 tons of iron ore consumed annually in this country, 7,000,000 tons are imported. Before the war, imports were steadily increasing, and home production declining. About half our pig-iron was made from imported ore, which yielded more iron per ton than the home ore. But for the war, we should probably have become increasingly dependent upon foreign ores. Recently the Government has instituted a special survey of our ore deposits, and it is giving practical assistance to iron mining, whilst a Department of the Ministry of Munitions, under the direction of Sir Lionel Phillips, is conducting investigations into our reserves of higher-grade ores, such as are needed for the production of special steels. The enterprise looks highly promising.

An official of the Ministry of Munitions, in a recent interview with a *Sheffield Telegraph* representative, said they had only began organising their present effort in March, 1917, but had succeeded in increasing the year's output by 1,500,000 tons, and would have done better but for labour disputes. They had made great economies by introducing

steam navvies and other mechanical appliances. As a result, the price should come down after the war. The Ministry had contributed to the cost of the new appliances. They were encouraging the calcination of ore at the place of production.

Regarding home supplies of iron ore and ironstone, there can be no doubt that we still possess vast reserves in this country, in spite of all the gloomy predictions about their early exhaustion that were published a few years ago. Professor Henry Louis, of the Armstrong College, Newcastle, is authority for the calculation that in Northamptonshire alone we have 1,000,000,000 tons of iron ore. Professor Fearnsides, of the Sheffield University, states that there is no district in England between Cleveland, in North Yorkshire, and the South Coast of Dorset, which is lacking in iron ore, whilst within 50 miles of a district that holds at least 50,000,000,000 tons of the very best non-anthracite coal, we have ready for mining or quarrying 5,000,000,000 tons of ore. "It will be sound policy," he says, "for this country to adopt the basic process of steel making on such a scale that, even with expanding trade, it will become unnecessary to purchase from foreign countries as large a quantity of ore as at present." Fortunately, the old prejudice against steel made by the basic process is breaking down in this country, and the importance of a wider utilisation of the ores suitable for this process, such as we are so lavishly endowed with, is at last being recognised. A rapid increase in the production of basic iron and steel is now being effected. A special report,* giving the latest information about our British iron ores, has been compiled by Mr. G. C. Lloyd, secretary of the Iron and Steel Institute, for the Department of Scientific and Industrial Research. This makes it abundantly clear that the country possesses vast reserves of various iron ores—hematites, magnetites, carbonate ores, oolites, and even limonites.

On the possibilities of Colonial supplies of ore we may quote from a communication of a few months ago to the *Financial News*, by Dr. P. T. McGrath. Dealing with the ores of Newfoundland, he observes that some of the iron mines located at Belle Island, some 20 miles from St. John's, are among the most remarkable in the world. There are two distinct beds of ore cropping out on the island, and extending many miles under the sea. One of them, owned by the Dominion Steel Company and the Nova Scotia Steel and Coal Company, is credited with 600,000,000 tons. Another mine owned by the Nova Scotia Company is estimated to contain about 2,000,000,000 tons. Centuries must elapse before the areas can be regarded as having been seriously impaired. These iron deposits possess the advantage that they are right on tidewater, and an authority of world-wide repute has stated that, "considering the small cost of mining and transportation, it is obvious that this ore can be placed on any Atlantic Coast market, whether in Europe or America, at a lower cost per unit of iron than any known competitive ore." Before the war, much of this ore was sold in Germany. The working of these mines occupies about 1,000 Newfoundlanders during some periods of the year, and about twice that number in the winter. The men engaged are those who carry on the fishery during the summer months, and turn their hands to mine work when the fishery is no longer possible. The location of the ore belt is such that by means of short tramways the product is conveyed to the coast, about a mile or more from the pit mouth, and there the material is placed in pockets constructed on the side of the cliffs, from which, in turn, it runs into great wooden structures on the piers, and from thence into the holds of the steamers. Loading is so expeditiously done that ships of 7,000 tons can be loaded in about six or seven hours. The material is then conveyed to the Nova Scotia points, where the smelters are located. It is believed that after the war, in pursuance of the policy of further developing the resources of the British Empire, the output of these mines will be greatly increased and the material used in British smelters in the same way as before the war it was used in Germany.

It is reported that the percentage of phosphorus contained in this ore renders it unsuitable for making the highest class of steel, but it is of a remarkably uniform quality, and is excellent for the making of basic steels. With special steamers and reasonable shipping freights, the importation of this ore into Britain should prove as economical, comparatively, as that of various Scandinavian ores was before the war.

If reports about the early exhaustion of the iron ores of Spain should prove correct, the question of developing the reserves of South Africa and even Australia will come within range of practical commercial economics. The Union of South Africa possesses very extensive deposits of various qualities of ore. In the Cape Province, some of the reserves are of the best hematite quality. In the Transvaal some enormous deposits are known to exist, and the quality of some of these has proved to be very good. In fact, some excellent ore has been proved about forty or fifty miles from Pretoria. Some of the South African iron deposits are near the railway system, and others could easily be linked up. In all, the States of the Commonwealth of Australia, iron ores abound, the most notable being those known as the Iron Knob and the Iron Monarch of South Australia, and of the Blythe River ironfield in Tasmania. These ores are of a quality that would be welcomed in this country if shipping freights could be got to an economical level, as, probably, they will in the not remote future. New Zealand, too, is known to possess immense deposits of iron ore. The same remark applies to India. Thus, it is clear that neither Britain in particular, nor the British Empire in general, is in any danger of becoming industrially bankrupt through lack of iron ore.

* This report is published by H.M. Stationery Office, price 2s.

NOTES.

A New Type of Iron-Concrete Arch.

During the months of August-September, 1914, a number of masonry bridges were destroyed on the Chemins de fer de l'Est. On the retreat of the Germans, it became necessary to restore these structures with the least possible delay. The plan adopted was to bridge the gap with rails bent to the curvature of the arch. These rails served, in the first place, as centreing for the deposition of the concrete with which the arch ring was completed, but being embedded in this concrete, they constituted, at the same time, a permanent re-inforcement. The results proved so satisfactory that the French Government sanctioned the building at Melun of an experimental arch, constructed on the same general system in order to subject it to a thorough test. A description of this arch is given by M. Frontard in a recent issue of the *Annales des Pont et Chaussées*. This experimental arch had a span of 25 metres and a rise of 2 meters only. Its thickness was 0.6 metres, and width 1.8 metres. The metal work consisted of three arched frames, 0.45 metres deep each, built up of four 70 mm. by 70 mm. by 7 mm. angles, latticed with flats, 50 mm. by 6 mm. These ribs were spaced at 70 cm. centres, and were cross-connected by angles. This light-steel framework was then filled in with concrete. The shuttering used was supported from the steelwork, and no other centreing was required. The concrete consisted of 0.800 cub. m. of gravel, 0.400 cub. m. of coarse sand, and 400 kg. of portland cement. It was deposited in 20 sections, each to the full depth of the arch ring. In the first stage, six of these sections were cast, equally distributed over the span. When these were set, an additional eight sections were deposited, and the arch was then completed by filling the remaining gaps. Care was taken throughout this work to distribute the load over the metal work as uniformly as possible. Until the completion of the concreting, the whole of the load was carried by the steel arch, which was in this way given an initial compression, which it retained permanently. As in the completed bridge the function of the steel is to take the tensile stresses due to inequalities in the loading, this plan of giving it an initial compression adds to the security of the structure. After completion, the arch was very thoroughly tested. This was done by piling on to it old paving blocks to a depth sufficient to impose a load of 1,860 kg. per sq. m. In the first test, this load was applied to one half the arch only. In the second test, the central portion of the arch was loaded, the load extending on each side to a distance of one-quarter span from the crown. Finally, the whole of the arch was loaded. The load imposed was about three times that specified in the official regulations for highway bridges, and this load was carried without the development anywhere of any sign of weakness. Careful arrangements were made for measuring the deformation of the structure, and the observations taken are said to have been in satisfactory agreement with the calculated values.

Reactions between Solid Substances.

The old dictum that substances will not react with one another, except when in the fluid condition, seemed to be rudely shaken, when Walthère Spring, of Liége, demonstrated, more than 30 years ago, that neutral salts like sodium carbonate and barium sulphate underwent mutual decomposition (into $BaCO_3$ and Na_2SO_4), when the dry salts were disintegrated and mixed, and the mixture was exposed to pressures of several thousand atmospheres. There was the obvious objection, however, that the solids might have been liquefied by the heat, resulting from the compression, especially considering that the pressure between the solid particles would hardly be uniform, as in hydrostatic compression, but that locally very high shearing stress might be set up. In that case, the reacting bodies might melt and would, after all, be fluid, and the further consideration that it seems to be almost impossible to exclude all traces of moisture from powdered salts, and that all bodies seem to be volatile to a certain extent—which may be very small—would only confirm the old dictum. That, in fact, appears to be the modern view of the problem. Carey Lea showed, in 1891, that high shearing stress, produced by grinding the substances in a mortar, was more powerful, apparently, to produce reaction than ordinary high pressure and even heating. On the other hand, Perman obtained certain combination effects simply by mixing dried powders; mixtures of colourless salts then showed the colours characteristic of the decomposition products, which had evidently been formed in the vapour state. When, in 1914, Dr. Leslie H. Parker took this investigation up in the Imperial College of Science, South Kensington, he demonstrated the latter point in a simple way. He placed a shallow cup, filled with potassium iodide, KI (practically non-volatile), and another charged with mercury chloride, $HgCl_2$ (volatile) next to one another in a desiccator joined to an air pump. Both the salts are colourless, but the KI turned red in 15 minutes in the slightly-heated vessel, because a film of red HgI_2 formed on it, whilst the $HgCl_2$, which was not assailed by vapours from the KI in the other cup, remained colourless in its own cup. Parker studied particularly reactions produced by trituration, *i.e.*, by grinding dry powders together, experimenting with nitrates, acetates, chromates, &c., of alkalis, silver, lead, &c., under conditions which would yield coloured decomposition products, and he easily obtained distinct evidence of reactions due to the shearing stress. But, like Spring, he sometimes observed that a decomposition seemed to continue after a cessation of the stress. Thus, Na_2CO_3 and $BaSO_4$ were dried, mixed and ground for 30 minutes. Immediately after grinding, a decomposition amounting to 2.4 per cent. of the mixture was observed. Seven and 14 days later the decomposition had affected 2.5 and 2.7 per cent. It looked, therefore, as if the materials were fused under the shearing stress, and resumed the solid state—in a few cases, at any rate—very slowly, so that the reaction could continue after removal of the stress. The question now arose: Which is the chief agent concerned, the heat or the fusion? If it merely be the heat, the velocity of the reaction should continue to increase, as the temperature is raised; if fusion be the essential factor, the velocity of reaction should also increase with the rise of temperature, but should increase much more rapidly as soon as the melting point of the mixture be reached. Parker's most recent researches (Journal of the Chemical Society, May, 1918) decidedly speak for the fusion effect. In these experiments the salt mixtures were only heated, not compressed. The relations are, no doubt, complex; in the case of the experiments with silver nitrate and sodium carbonate, *e.g.*, there

would, in the partly-fused mixture, be present four solid phases, and one liquid and one gaseous phase. But the importance of fusion—as distinct from the thermal effect—seems clearly to be established. Regulation should also be taken into consideration, especially in the cases of ice and bismuth, and our readers will remember the experiments of the late Sir W. Roberts-Austen on the diffusion of one metal into another; one of his metals was fused or hot, however. Lastly, it has often been suggested that metallic atoms will travel at particular rates through other metals with the electric current, when the current is applied to an alloy or to a gold plate which is pressed against a plate of antimony, *e.g.*; but when Sir J. J. Thomson* lectured on the thermal conductivity of metals in May, 1915, he stated that he had failed to obtain any trace of such a omic movements.

INDUSTRIAL NOTES.

THE object of the Workmen's Compensation (Silicosis) Bill, just introduced into the House of Commons, is to provide compensation in the case of persons who are killed or disabled by the industrial disease called fibroid phthisis, which is caused by the inhalation of certain kinds of siliceous dust and occurs in several industries in this country, particularly in what are known as the refractories industries (including the mining and quarrying of ganister rock and the making of silica bricks). The question of the extension of the Workmen's Compensation Act to this disease by Home Office Order was considered by the Industrial Diseases Committee, 1907, but in view of the difficulties arising out of the particular nature of the disease—its slow growth, difficulty of distinguishing it in its early stages from other respiratory affections, &c.—they were unable to recommend that it should be brought under that Act. Since that committee reported, the disease has been the subject of much investigation, both in this and other countries, and it has now been found possible to work out a scheme of compensation on special lines which it is believed will meet the difficulties of the case. The main feature of the scheme is the establishment of a General Compensation Fund for the particular industry or group of industries to which employers in the industry will be required to subscribe, and out of which all claims for compensation will be paid. It is also proposed to make special arrangements for the medical examination of the workers.

The following are some recent decisions given by the Committee on Production on cases which have been referred to them by the Ministry of Labour, including cases arising out of the Orders under which a bonus to munition workers has been given:—Shipbuilding trade: Drillers and hole cutters are to receive an advance of 20 per cent. on their piece work rates from March 12, 1918; all previous additions granted since the outbreak of war are to be merged in the advance now given with the exception of the general advance of 10 per cent. granted in March, 1915, the advances of 13*s.* a week granted in 1917 and the 7½ per cent. bonus on earnings. Lightermen and watchmen, London: The men concerned are to receive an increase of 1*s.* a day in the war wage advance, variable advances are given to apprentices, and the rates for overtime, Sunday work and night work are revised from June 14, 1918. Railway shopmen, Ireland: The rates of 60*s.* a week to light platers and 64*s.* a week to angle-iron smiths (including war wage advances) are to be increased to 61*s.* and 65*s.* a week respectively (including war wage advances). Applications for increases in the wages of iron moulders, steam engine makers, riveters, and heavy platers have not been acceded to.

Colonel Sir Charles Allen, V.D., chairman of the Ebbw Vale Steel, Iron and Coal Company, Limited, presided at the fifty-first ordinary general meeting of the shareholders, held in London on the 19th inst., and stated, as a convincing proof of the volume of work executed under the present strenuous conditions, that the wages paid to the workmen exceeded all previous records, amounting to over 2,000,000*l.* In addition to this, the company had continued their grant to the dependents of their officials and workmen still gallantly fighting the country's battles, the amount distributed this year being 35,000*l.*, bringing up the total since the outbreak of war to about 150,000*l.*

Dealing with the perilous position of the iron and steel trade in this country prior to the outbreak of war, Sir Charles said it was impossible to forget that the unscrupulous dumping process of the Germans had nearly succeeded in driving our ordinary heavy steel trade on the rocks of ruination. Fortunately, this incubus was being effectually removed, with no chance of its ever appearing again. Manufacturers could expand without the fear of being stifled by unfair treatment. It therefore became more than ever a question of national and vital importance to make up for lost time by encouraging the production of home industries. He wished particularly to emphasise the fact that the Ebbw Vale Company would be the first establishment in South Wales producing steel entirely independent of foreign imports of raw materials. He reminded the meeting that it was about four years ago that the board paid their first visit of inspection to the iron ore bearing properties in Northamptonshire in contemplation of providing for their needs a regular supply of mineral from the deposits in this country. Since then, as reported from time to time at general meetings, the company had concluded a purchase of an extensive property, which was estimated to yield a mineral eminently suited to their steel-making process, and to satisfy the company's needs for at least the next forty years upon such terms as would always compare most favourably with the lowest prices of imported ore of a similar character. Step by step in all their deliberations the board had consulted and been guided by the advice of the most reliable and experienced experts available. This had been their ambition for years past, and might be regarded as the main plank in their broad policy of expansion as iron and steel manufacturers.

It was possible, added the speaker, that some shareholders might imagine that the expenditure already incurred upon plant for the production of munitions of war might become unproductive when peace was restored. He was anxious that it should be distinctly understood that such was not the case, and every penny outlay on expansion could be turned to profitable account whenever the demand for war material ceased.

In the course of his remarks at the annual general meeting of the shareholders of Messrs. Brunner, Mond and Co., Limited, held in Liverpool last Friday Mr. Roscoe Brunner, chairman of the directors, stated the following:—". . . Mr. Milton Sharp, the chairman of the Bradford Dyers' Association, addressing his shareholders in February last, made an appeal to some of the great chemical concerns of the country, including ourselves, Messrs. Castner-Kellner's, the United Alkali Company, the Gas, Light and Coke Company, the South Metropolitan Gas Company, and others, to give financial aid to the dye industry. We did not think then, nor do we now, that the dye trade was likely to fail for want of financial support. One section of it had the Government at its back, and I am quite certain that had any dye maker been in need of funds those funds would have been forthcoming at once. Our idea was that there should be in the chemical trade four groups of heavy chemicals, such as acids, alkalis, &c., which we make; a dye group, an explosives group, and a fine chemicals group. We have no quarrel at all with the proposed amalgamation which apparently is near at hand in the dye industry. We have, again, no quarrel with the merger, as they call it, in the explosives group, nor do we complain at all if those two groups should themselves come closer together, as seems likely, because they are themselves very intimately connected the one with the other; but we think we are entitled to say that just as we do not intend to butt into their trade, so we think they should respect ours. Speaking only for our friends and allied companies, we are prepared at all times to supply the dye industry with our products as their raw materials at reasonable prices, and we are prepared, should it be found proper, to make intermediates for the dye industry, and we think that in the case of some of the intermediates we are better fitted to make them than they are themselves. Again, we should be prepared to sell to them those intermediates, if we made them, at reasonable prices. As a matter of tonnage to us, who are used to calculating in hundreds of thousands of tons a week, the tonnage which the dye trade would require from us seems small, but the textile trades, which depend so largely on the dye trade for their life blood, are big customers of ours, and it is up to us to help the dye trade not only to establish the industry in this country, but also to help the textile trades to keep the great business that they have already established. Thus, while we wish the dye trade well, and are prepared to help that trade all we can, we cannot expect, nor do we wish, to sell our products at such prices as will realise a fortune for ourselves. . . ."

Speaking at the meeting of the National Machine Tool Builders' Association held in May, at Atlantic City, N.J., Mr. I. F. Marcosson, war correspondent, pointed out, according to *The Iron Age*, New York, the hideous danger of the German propaganda. He stated that sinister, silent and subtle agents were going about, and their work aimed at two things. One was to end the war now or as quickly as possible; the other was to build up a trade for Germany after the war. Germany was preparing for a trade offensive when actual hostilities had ceased, and he had recently seen signs in Stockholm, Christiania and Copenhagen of the work which German agents were doing in trying to keep Germany's foreign trade alive. The nation that controls raw materials, he added, will rule the world trade. There were more than 1,000,000 Germans in Russia, and they were going to rebuild that country into a great economic asset for Germany. In Spain, Mr. Marcosson further stated, he saw the finest industrial secret service in the world maintained by Germany. He predicted that for at least a few years after the war, many German articles would be assembled or shipped from Spain and other European countries, bearing the stamp "Made in Spain" or "Made in Switzerland." Germany was seeking by every means to import American-made machine tools through neutral countries, and the regulations pertaining to shipments of raw materials and finished machinery to neutral countries could not be made too strict.

A porter and messenger employed by a varnish merchant was sent on an errand to an oil and colour warehouse in Central London. Whilst there, a raid took place, the warehouse was struck by a bomb, was set on fire and collapsed. After the fire had been got under, the man's body was recovered. The County Court judge found that the death was caused by an accident arising out of, as well as in the course of, the employment of the man, and he awarded the widow compensation.

The employer appealed, and the appeal came a few days ago before the Master of the Rolls, Lord Justice Banks and Mr. Justice Neville. Last Monday, their lordships dismissed the appeal.

The Master of the Rolls said: "It was not disputed that the workman met his death 'in the course of' his employment, but it was denied that the event arose 'out of' his employment." His lordship then stated the facts, adding: "The learned judge on the evidence, and in a very careful judgment, came to the conclusion that the employment of the man exposed him in a special way to the common danger from air raids, so as to render the risk which he ran a risk incidental to his employment. He found that the inherent conditions of inflammability of the goods contained in this oil and colour warehouse threw upon the building a special and additional risk of fire, which exposed the persons employed there to special dangers from fire, and accordingly that the man was thus exposed to a risk not shared by other members of the public in the vicinity, whether in the streets or in neighbouring buildings. The judge further found, as an inference from the facts proved, that the man died from suffocation by smoke. He thus found that the man met his death by an accident arising out of, and in the course of, his employment. In my opinion, there was evidence, carefully and exhaustively reviewed and analysed by the judge, from which the conclusions of fact at which he arrived might reasonably and properly be drawn. Accordingly the appeal fails."

Lord Justice Banks gave judgment to the same effect and Mr. Justice Neville concurred in dismissing the appeal.

INCREASE IN THE PRICE OF COAL.—The Board of Trade have made an Order increasing the price of all coal as from Monday, June 24. The amount of the increase is 2*s.* 6*d.* per ton, except in the case of shipments to France and Italy, in which cases the amount of the increase is 5*s.* per ton, the additional 2*s.* 6*d.* in these cases corresponding to the war wage increase of 2*s.* 6*d.* per ton which was not applied to shipments to France and Italy in October last. The increase corresponds to increases in the costs of working at the collieries in respect of which no increase has been made (except in South Wales and Monmouth and the Forest of Dean) since prices were limited by the Price of Coal (Limitation) Act in July, 1915. The Order provides that where the price under any contract is increased under its provisions the prices under subsidiary contracts shall be increased by the same amount. The increase in colliery prices entails a corresponding increase in retail prices.

WATER POWER RESOURCES COMMITTEE.—The Board of Trade have appointed, with the concurrence of the Ministry of Reconstruction, the following gentlemen to be a committee to examine and report upon the water power resources of the United Kingdom and the extent to which they can be made available for industrial purposes: Sir John F. C. Snell, M.I.C.E. (chairman); Mr. G. S. Albright; Sir Dugald Clerk, J.P., D.Sc., F.R.S., M.Inst.C.E., M.I.Mech.E.; Dr. J. F. Crowley; Mr. H. F. Carlill, Board of Trade; Mr. Philip Dawson; Professor Gibson, D.Sc., M.I.M.E.; Mr. Vernon Hartshorn, J.P.; Dr. H. R. Mill, D.Sc., LL.D.; Mr. A. Newlands, M.Inst.C.E.; Mr. G. C. Vyle, representing the Associated Chambers of Commerce in the United Kingdom; Mr. A. J. Walter, K.C.; Mr. Ralph Walter, Ministry of Reconstruction; and Mr. D. J. Williams. Mr. R. T. G. French is the secretary, and all communications intended for the Water Power Resources Committee should be addressed to him at 10, Princes-street, Westminster, London S.W. 1.

* See ENGINEERING, May 21, 1915.

THE WORLD'S LARGEST SHIPYARD AT HOG ISLAND ON THE DELAWARE.

FIG. 5. GENERAL VIEW OF THE WET DOCK BASINS; THIRTY WEEKS AFTER THE WORK ON THE YARD WAS COMMENCED.

FOR a long time we felt that Britain carried on her back the main load in the effort to win the war, as far as the provision of money, munitions and of ships was concerned. It was a heavy burden, and it was a relief to realise that America, with her immense resources, was coming to our assistance. That did not mean that we were going to do less, but that our friends across the Atlantic were going to add their labour and wealth to that of the Allies in order to secure the desired result. How much she can do, and will do, was not adequately realised either by ourselves or by the Germans, and it is doubtful whether we yet really know what a wonderful ally the enemy has secured for us by his wilful defiance of international law. It may help us to a better appreciation of the facts if we take a single outstanding example of what is being done in America to neutralise the efforts of the U-boats, and to provide transport for the hundreds of thousands of men who are being trained as soldiers. A good example is found in the construction of the largest shipyard in the world, which was commenced on September 20, 1917, and is now so far advanced that the twenty-first slipway is in use, and 29 other slipways are under construction. Fig. 1, on page 726, shows what the site was like last year, while the other views on the same and the present page, show the wonderful transformation which has taken place in a few months.

A shipyard capable of having 50 ships on the stocks at the same time was a thing quite undreamed of until last year. It lay entirely outside of practical commercial possibilities, and suggested the visions of Jules Verne rather than the plans of sane business men. Yet it is now in a fair way of accomplishment, so that we may accept the estimate of 50 ships being built simultaneously while 28 others are being fitted out at seven piers each of a length of 1,000 ft. When that stage is reached there will be a launch every other day, either of a 7,500-ton cargo ship, or of an 8,000-ton combined troop and cargo boat. When we consider how steadily we are tightening our control on the German submarine, and study the decreasing tale of its successes, the significance of this great output will be the better realised.

To complete 4,000 tons of plates and frames each day would be beyond the possibilities of the site, although it covers 846 acres and extends over 2 miles of river front. The various parts of the vessels are being "fabricated" all over the States at 3,500 different works, some of them so remote that the average journey is no less than 20 days. Even with this assistance the place is a busy hive. Barracks have been erected for 6,000 men, the remainder being drawn from outside. Within five months of commencing operations 26,000 men were employed on the construction of the yard. Sewerage, water supply and fire-fighting appliances have been provided, besides canteens, classifying yards and stores. The site is on Hog Island, just outside Philadelphia, on the Delaware River, and is well inland, away from possible enemy attack.

SOME OUTSTANDING PROBLEMS IN AERONAUTICS.*

By DR. DURAND.

WHAT the aeroplane has become in this short but poignant decade of the world's history, and what it stands for to-day, this audience knows too well to need specification in detail.

The Problem of Constructive Materials.—Perhaps nowhere is there to be found a better illustration of the interdependence of technical and scientific research and study than in the manifold advances in various technical and scientific lines which conjointly have made the aeroplane in its present form a structural possibility.

The structural problem of the aeroplane is one of strength in relation to weight. For the main elements comprising the skeleton of the structure, wood has, thus far, held the main place, with metal construction steadily attracting more and more interest and assuming a place of growing importance, at least in the study of new designs. We may be well assured that however good may be any solution which we may reach of the many problems presented to us in the industrial arts, there are, as a matter of fact, series of better ones only awaiting our patient study. This is indeed a fundamental truth of which we should never lose sight. We may be, for the moment, satisfied with our solution of a problem in technical industry; we may be able to see nothing better, and yet we may be well assured that, as a simple matter of fact, there is something better. This is a perfectly safe assertion, if only as based on the law of probability of our having, at any given time, reached the final optimum possible combination capable of furnishing a solution of the problem. Thus, as applied to the problem of constructing the framework of the fuselage of an aeroplane, or of combining together wing spars and ribs in such manner as to form a wing skeleton, we may be sure, however good our present practice may be and however satisfactory it may seem, that in reality it is not the best and that long series of better solutions only await our intelligent and patient study.

It certainly stands before us as a problem for the near future to pass in review most thoroughly the entire range of constructive materials, metallic as well as wood, and to determine, in the light of the experience which we are so rapidly accumulating during these days of storm and stress in military aeronautics, the combinations of materials which may serve to give the most efficient service on the minimum of weight. This stands out as one of the great problems of aeronautic engineering, that of the best materials and of their best use. Much has already been done, but much yet remains, and rich rewards most assuredly await patient and well directed work in this field.

The Problem of Size.—One of the most interesting of the problems presented to the aeronautic engineer is that of the limiting size and carrying capacity of aeroplanes. Is there such a limit? If so, what is it? Why is it? And how may it be removed or extended?

In dealing with this problem we come, of necessity, into contact with the laws of similitude of geometrically similar structures. It is well known that under simple

* Paper, slightly abridged, read before the Aeronautical Society of Great Britain at the sixth "Wilbur Wright" lecture in the Central Hall, Westminster, on Tuesday, June 25.

modes of loading, geometrically similar structures of wing and fuselage will have similar factors of safety under equal unit loads. But for such structures, if strictly similar geometrically, the weights themselves will increase as the cubes of the similar dimensions, while the areas of wing or supporting surface will only increase as the square, and hence the ratio of weight to area will continuously increase as the linear dimension.

Were we indeed subject, without recourse, to the operation of this law of mechanics and geometry we should be in a sorry state regarding the future development of the aeroplane as regards size and carrying capacity. We should be limited strictly within the bounds of the developments made possible by improvements and advances. But fortunately for the future of aerial navigation, we are not so limited and there seems no reason why, at the present time at least, we should need to anticipate any especial limit as necessarily imposed on aeroplane construction, as regards either size or carrying capacity.

We are able to escape from the consequences of this law due to two facts.

1. It is not necessary that a large element of an aeroplane, a wing in particular, should be geometrically similar in structural characteristics to a small one. For a certain size the structural elements will partake of certain characteristics. As the over-all size increases, these elements may take on new characteristics. Those which had been solid may now become hollow or of lattice or built up form. The law of geometrical similitude will not hold and the weight will not necessarily increase in ratio with the cube of the over-all linear dimensions.

2. It is by no means necessary that a large aeroplane shall be, in its general form, a geometrical copy of a small one. While both will have similar elements, such elements need not be the same in number or arrangement. In fact one of the most obvious of means for increasing lifting power is to increase the number of the wings or lifting elements. There is no reason, at least structurally, why wings and connecting elements should not be increased in number beyond anything now in use or even considered—increased to a point which would give a size and lifting power great enough to meet any demands which we can now formulate or which the future seems likely to present.

Structurally, therefore, the problem of increased size presents three problems as follows :—

1. The structural problem of so developing the character of the elements of aeroplane construction, such as wing spars, longerons, struts, ribs, &c., that with increase in over-all dimension the weight shall not increase sensibly faster than as the square of such dimension.

2. The structural problem of combining the larger elements of aeroplane construction such as wings, fuselages, or engine nacelles with their connecting structures, in such manner as to secure, for a given wing area, the minimum weight of secondary structure.

3. The aerodynamic problem of combining multiple wing elements in such manner as to reduce to a minimum the interference of one with another. This is a problem which opens fascinating possibilities to the student of experimental aerodynamics—a problem on which already some beginnings have been made, but one far from a final or as yet wholly satisfactory solution, and one on which the future development of greatly increased size and carrying capacity seems destined largely to depend.

In short, then, so far as increase in size is concerned, there seems no reason to apprehend any particular limit, or any serious difficulty on the part of the scientist and the engineer in meeting the demands of the future in these respects. The difficulties seem no greater than those which have been overcome in the case of ocean shipping as shown by the continuous development from the early beginning of the application of engine power to ocean navigation during the first half of the last century down to the mammoth floating structures of the present time; and if we may take any indication from the accelerated rate of progress which has characterised the entire history of aerial navigation, we may feel confident that we shall not have to wait a half or three quarters of a century for a parallel development in the latter field.

Variable Wing Area or Variable Wing Camber.—To mention only one of the many remaining problems which are connected with the design and construction of the aeroplane itself, a word may be said with regard to the problem of variable wing area. Broadly speaking, the ideal aeroplane should be able to change its wing area in accordance with the conditions and circumstances of flight. For ease in getting off the ground at a moderate speed, for ease in landing likewise at a moderate or low speed, there is need of a relatively large area of wing or supporting surface. For the attainment of high speed, reduced wing areas are needed, and are furthermore sufficient for the support of the weight at such high speeds. The supporting force gained by a given form of aeroplane wing depends on the area, the speed and the angle of attack, and there will be some combination best for each set of conditions. To meet these conditions, varying from time to time throughout the course of a flight, a correlative variation in wing area is needed.

To some extent the same ends may be met by changing the camber or curvature and form of the fore and aft section of the wing. Thus, when the camber or fore and aft curvature is increased, the form will be more suitable for landing at a reduced speed, while with curve flattened and camber reduced, the form will more readily favour the attainment of relatively high speed.

The problem of an adjustable wing, either as to extent of area or camber or both, is a favourite one with students of aeronautics, and we may hope for some measure of useful and practical solution. Thus far, of the many devices and forms proposed, none has so far fully justified itself as an altogether satisfactory and practical solution of the problem.

Motive Power.—Passing now to the motive power and its application to the propulsion of the aeroplane, a most interesting and important series of problems challenges our attention. Only the more important can be noted here.

Fuel.—One of the most important of these is that of fuel. What is to be the future fuel for the aeroplane, or for aerial navigation in its wider aspects? How long will our stores of crude petroleum oil from which we now obtain our petrol or essence or gasoline, as it is variously termed, continue to furnish this all-important element in the present programme of power development? Doubtless there are large stores of petroleum oils yet undiscovered, but we may safely assume that we are using up a supply in the nature of a bank deposit.

With regard to the question of fuels, we need not go so far afield as to look into the coming decades for interesting and important problems. Perhaps the one most pressing for present solution is the question of what is the best fuel for the modern aviation engine, having in view the three requirements—power, economy, with reliability and durability. Out of the exigencies of the present war have come many serious and extended researches relating to the problems of military aviation, and of these none is perhaps of greater significance regarding the future of commercial aviation than the studies which have been made regarding aviation fuels. While matters relating to the problems of military aeronautics must be spoken of with much reserve, it will perhaps be permissible to say before this audience that from these studies three principal results seem to have been rather definitely established. These are :—

(a) As between the various grades of aviation motor fuels which have been used during recent years, and comprising a rather wide range of composition and of physical and technical characteristics, there is but little to choose from the standpoint of power or economy alone. This assumes, of course, that the fuel is a genuine motor fuel and the results regarding power or economy relate to an assumed period of effective operation under such fuel. It must not, however, be assumed that there are no differences in power or economy traceable to the fuel employed, for such is far from being the case. It is, however, within the limits of reasonable statement to say that such differences are relatively small and under most circumstances would not, of themselves, constitute a determining or controlling factor.

(b) As between such motor fuels marked differences do seem to be indicated as regards their influence on the life and reliability of the motor, especially on long time tests, or in actual service on long time flights.

(c) For the various fuels, in order to realise the best results either as regards power, economy, or life and reliability, special and individual carburettor adjustments are necessary, and such as can only be determined by trial under actual working conditions.

It may perhaps be further said that the problem of an excellent and reliable motor fuel for aviation purposes seems to have been satisfactorily solved. Its specifications and range of characteristics, physical and chemical, are pretty well established, and so long as our source of motor fuel supply is to be found in petroleum derivatives, we seem to have reached a reasonably satisfactory determination of the best combinations of such derivatives for the various requirements of aviation service. These characteristics, which must be considered as a part of the great body of military information and which cannot for the moment be put down in plain print, we may hope will, in due time, become available in the arts of peace and for the development of commercial aviation in its various fields of promise.

With the problem of fuel, that of the prime mover or engine is closely related. Is the present type of engine to continue, or is it only a passing stage on the way to some more perfect form? This is a question, interesting indeed for speculation, but hardly to be considered in comparison with actual present moment problems. The present engine and its application to the propulsion of the aeroplane does, furthermore, present no lack of interesting and important problems, and among these a few of the more pressing may here be noted.

First, the problem of gross power. How much power can we put in an aeroplane or airship of no matter what type or form? This divides immediately into three subsidiary problems as follows :—

1. How much power from a single cylinder?
2. How many cylinders for a single engine?
3. How many engines for a single airship?

In the way of power per cylinder we are now reaching close about 40 h.p. as a maximum.

In the way of cylinders per engine we have reached a stage of development where the 12-cylinder engine is quite a standard type and higher numbers such as 16 and 18 represent only questions of detail. It is not too much to say that the 600 h.p. engine is quite within the reach of present practice and may be realised as called for. We have long since become accustomed to two and three engines on a single plane and are now seeing four engines in various recent designs. It is therefore clear that if a power plant of 2,500 h.p. on a single structure is wanted, it is quite within the scope of present practice to realise and provide such a plant.

And if four engines of 500 h.p. or 600 h.p. each, there is no reason why the number may not be increased, at least to a point beyond the present apparent need for power on a single structure.

On the other hand, it must be admitted that, having in view the limitations of present practice, the most simple and in fact the only reliable way of extending power is by a multiplication of the number of cylinders rather than by an increase in the size of the latter. The fact that a 2,000 h.p. equipment would presumably require from 40 to 60 cylinders shows the formidable degree of multiplication of small elements required to realise such a result. The real problem of size or capacity of engine is therefore one of power in a single cylinder. What can be expected in this direction, and in what way shall search be directed?

The present limitation arises largely as a matter of cooling and it is in this direction that search may well be made for ways and means of effectively increasing the power capacity of a single cylinder in an engine of the aviation type. This is a problem which is distinctly outstanding and well worth our serious attention and study.

The Carburettor.—Another problem connected with the engine is that of the carburettor. At the start of aeronautic engineering the carburettor naturally took its initial form and arrangement from the already fairly well developed automobile engine carburettor. This was but natural since both engines are of the same type and both use the same general form of fuel. In respect of the conditions of operation, however, there is a marked and important difference. The automobile operates at or near a fixed level and hence in an atmospheric medium of sensibly fixed pressure and density. With the aeroplane the case is very different. The latter may change its level by thousands of feet in a few minutes or even seconds, as in vertical or nearly vertical dives, rapid spirals, &c. This difference in the conditions of operation introduces a factor of distinct significance and of great importance in the design and disposition of the carburettor. Experience in the air has clearly shown the importance of this new factor, and it is not too much to say that the problem of the entirely satisfactory carburettor, capable of automatically answering to the various atmospheric conditions under which it must work, is distinctly an outstanding problem. It is true that much progress has been made, and as the result of laboratory research, checked by actual experience in the air, we now know much better than, say, two years ago, the fundamental conditions which must be met by the carburettor for the aeronautic engine. The present solution can hardly be considered as final however, and we may fairly admit that the whole problem of carburation, including the manifold supply of the carburetted mixture to a multi-cylinder engine, should, as soon as may be, receive a thorough and fundamental re-study in the light of the information to be drawn from the experience of the past three or four years.

Ignition.—Another problem which we should view as outstanding is that of ignition. It is true that ignition, as now realised with the best equipment, seems to be fairly reliable and effective. But the whole programme is open to the objection of requiring an entire electric power plant of a highly specialised type, together with electric conductors and the spark plug for producing the spark between the discharge points within the cylinder. This ensemble, comprising electric generator or magneto, electric cable, distributor for sending the spark with proper timing to the various cylinders and spark plug with discharge points within the cylinder, represents a very complicated and highly specialised device for producing the initial ignition within the body of compressed fuel mixture. In its present state it is a marvel of scientific and technical development, and it does its work; but it is complicated and subject to many possible modes of derangement, and, as we all know, has been and is still the seat of some of the most serious of the engine difficulties to which the power plant as a whole is subject.

I have never been able to persuade myself that this exceedingly complicated and specialised auxiliary equipment was to be the final solution of the problem of producing ignition in an internal combustion engine. If we can anticipate the explosion engine of the year 1968, assuming that our grandchildren are still dependent on hydrocarbure fuels at that date (and furthermore that they are still available), it would seem as though some more direct and simple mode of initiating the combustion in the cylinders would have been found. Still, otherwise, we may say that on the law of probability, the chances are overwhelmingly against our having at the present moment developed the very best method of ignition. The laws of physics and chemistry, by a probability which almost reaches certainty, contain some potential combination of factors which will permit of eliminating much of the complexity and delicacy of adjustment which is so characteristic a feature of the present mode.

It is perhaps proper to add here that studies in this direction have already been made, and with results which offer promise of interesting developments in the future. The path of perfection is likely to be not a short one, however, and we can see no prospect of any development in the to-morrow of progress likely to displace electric ignition. There must, however, be some better way, and if not to-morrow, then some other morrow should see it made available for use.

The problem of ignition is then one which is distinctly outstanding, one which by its importance merits the most careful study, and one which, at least, offers reasonable ground for hope of a successful and relatively simple substitute for the present mode.

(To be continued.)

GAS TRACTION INVESTIGATION.—The Gas Traction Committee has, with Mr. Walter Long's approval, appointed two additional members to the Expert Sub-Committee which is investigating the use of gas under compression for traction purposes. The new members of the Sub-Committee are Mr. G. J. Shave, of the London General Omnibus Company, Limited, and Mr. J. G. Clark, of the Gas Light and Coke Company.

STEAM AND POWER PLANT FOR CHEMICAL WORKS.

TO THE EDITOR OF ENGINEERING.

SIR,—My attention has just been directed to an article in your issue of May 17 last, headed "Steam and Power Plant for Chemical Works." On reading, this appears to present two outstanding features, one that it is couched in a tone of positive and didactic assertion usually foreign to the leading articles in ENGINEERING, the other that the statements thus laid down are often not such as to commend themselves to those who possess actual working acquaintance with the problems they elect to solve.

It is doubtless true that many chemical plants have been erected, and may still be under construction for Government Departments, on the lines advocated in the article. This is inevitable since there does not exist any recognised body of chemical engineers, nor the system of training necessary to produce them. Chemical works have suffered in the past as the article states from power engineers' lack of appreciation of conditions to be met, and this has strengthened an innate conservatism and distrust of change on the part of the management.

The all-important point of freedom from stoppage requires some emphasis. Unlike engineering shops generally, or even power stations, the chemical plant is in many cases required to run for 168 hours per week continuously. There are no easy periods at night or week-ends during which small repairs may be executed, frequently the plant shuts down only twice in the year, and the cost of any involuntary stoppage is generally out of all proportion to the actual repair occasioning it and rises at a rapidly increasing rate with the length of delay in re-starting.

In spite of this the writer's experience in erecting two factories and re-modelling two old ones leads to the belief that chemical power plants need not be so alienated from good engineering practice as the article referred to would suggest. Not to trespass too greatly on your space, two items only, boilers and electric supply, may be mentioned.

The article is correct in stating that very wide and rapid fluctuations in load must be looked for, but the deduction that water-tube boilers are not suitable would be regarded with doubt from warship practice alone. In one factory with which the writer is connected, having precisely this type of load, Lancashire boilers, intrinsically sound, have recently been replaced by water-tube. The results have been a cessation of stoking labour troubles (owing to easier work), a greatly reduced coal consumption and improved work from the chemical plant owing to better supply of steam at command and steadier pressure. The lack of reserve of the water-tube boiler is more than counterbalanced by its extreme flexibility.

The article advocates direct current on the curious grounds that conditions are usually bad for electrical work on account of the presence of steam and acid fumes and the existence of bare wires. Under such circumstances it approaches an optimism from which the article is usually free to state that commutation trouble has disappeared. On the other hand, the induction motor will run under appalling conditions of fume, dirt and grease without failure, it has a large safe overload capacity, and an oil-immersed star delta starter has been found absolutely fool-proof and possessing a clean repair sheet. Whereas variable speed is sometimes, but not very often, required, there are cases on the other hand wherein the induction motor's capacity for maintaining constant speed under variable load is valuable in increasing output.

Direct current is necessary for electrolytic work, but the pressure and current required are rarely of use for motor driving, so that in any case a converter set is needed.

If the wiring be well done and carefully supervised, unintentional bare wires need not be a determining factor, but on, for example, a 200-volt three-phase system, it is an advantage to run the lighting at 151 volts between a phase and neutral.

The article appears to fail in taking a large view of the problem. When this is done it will often, perhaps usually, be found that a balance can be determined under a scheme such as the following. High-pressure water-tube boilers supplying steam at high superheat to adjoining power-house providing power of all kinds, alternating current (and direct current if necessary), compressed air, water service, &c., &c. Exhaust steam from power-house still dry taken to chemical plant so arranged that principal users are near power-house. Exclusively electric driving remote from power-house.

It will be admitted that such a lay-out possesses some attraction for engineers, and there is ground for hope that it need not further be regarded as an unattainable counsel of perfection.

Yours faithfully,
L. A. F.

TO THE EDITOR OF ENGINEERING.

SIR,—The letter of your correspondent "Dum Spiro Spero" is very interesting as a perfect illustration of the attitude to be expected from power engineers when called in to advise on the above subject. His main contention, as I understand it, is that, since the chemical manufacturer is compelled to burn very large quantities of coal in any event to provide the steam heat he requires, he should, in the national interest, pass the whole of his steam through turbines in order to generate power at a very low cost, the excess power beyond his own requirements being used for electrochemical processes, or sold to neighbouring power users.

Now the amount of steam required for process purposes in a chemical works is almost always five or six times that necessary to produce the required power. To take two actual instances: one a small works driven by a number of small non-condensing engines, power required 200 h.p., or, say, 7,000 lb. steam per hour, average process steam used 40,000 lb. per hour; the other a large works with turbo-generators giving 1,600 kw., requiring, say, 37,000 lb. steam, and using 235,000 lb. process steam. Further, the amount of power in an average chemical works amounts to about 350 brake horse-power per 100,000*l.* worth of plant, and buildings, so that there are very few works in the country where turbines would be required.

Why, then, should the chemical manufacturer saddle himself with the great capital cost and running expenses of a central station capable of making use of all his steam? He certainly will not do so for patriotic reasons, and a proposition so far removed from the scope of his ordinary business would not be likely to appeal to him on other grounds. On the other hand, the loss of all that cheap power is undeniably deplorable. Why not, then, instead of trying to make the tail wag the dog, put your chemical works alongside a large public central station and get the station to provide themselves with back-pressure turbines which would supply exhaust steam to the chemical works at a reasonable pressure and superheat as your correspondent suggests? Such a scheme in normal times would be well worth looking into, though it is altogether outside the domain of practical politics in war time. It might, however, appeal to the Coal Conservation Committee for post-war consideration, and it will certainly be supported by any chemical manufacturers who were near, or could get near, to central stations who would relieve them of the necessity of steam generation by supplying it like power.

Before leaving the subject I would point out one enormous difficulty in the way of your correspondent's scheme, and that is the tremendously fluctuating nature of the process steam load in a chemical works. Your correspondent evidently does not believe in these fluctuations, but they exist nevertheless, and they would constitute a very awkward problem in handling the surplus power load. However, let us leave the academic side of the question and consider chemical works as they exist in practice. The chemical manufacturer is not going to generate a kilowatt more than he wants, and providing he uses his exhaust steam for process work, I repeat that it is absolutely immaterial how much steam he uses per kilowatt-hour, and that considerations of long-continued running without breakdown and a low repair bill will cause him to select slow or moderate speed engines, anyway up to 1,000 h.p., with turbines for larger powers. The latest craze for extra high pressure steam will not appeal to him in any way. What does your correspondent mean by the twofold increase of power with steam at 350 lb. per square inch as compared with 240 lb. per square inch? He will not get twice the power per ton of coal, or twice the power for the same money invested in boilers and turbo-generators.

Such high pressures would, of course, mean water-tube boilers. Now I am astonished to see that your correspondent claims that water-tube boilers respond better to a sudden large demand for steam than do Lancashire boilers, and that the latter do not admit of forcing to the same extent for a short period. This really is stretching the claims of water-tube boilers a little too far. It should be unnecessary to point out that the large water space of the Lancashire boiler provides a reserve of steam which can be drawn upon *instantly*, and which will give five or six times the normal steaming rate for short periods, without excessive priming, and I have myself frequently obtained 16,000 lb. of steam per boiler per hour over 3-hour periods from a battery of 30-ft. by 8-ft. boilers. On the other hand, the water space in a water-tube boiler is very small and consequently there is practically no reserve, and by the time faster firing has had time to take effect the pressure will have fallen seriously in case of a sudden demand. But the strongest reason why water-tube boilers are unsuitable for chemical works is this: All feed water is new water—there is no condensed water coming back, and consequently even with filters and softeners there will be more or less scale in time. With Lancashires this is not a serious matter, but with water-tube boilers it is extremely so. It may be suggested that the condensed water from coils, evaporators, drying ovens, and other process plant where the steam does not come in contact with the chemical materials might be collected and brought back to the boiler house. In practice, however, it is found that the risk of contamination from leaky coils, &c., is so great and so frequent, that it is better not to do this. It is preferable to use this clean hot water in the processes.

The subject of air compressors, raised by your correspondent, is an important one—the power required for these often amounting to 25 per cent. of the total power required. If alternating current is employed, the use of synchronous motors with leading power factor is certainly the right thing, in order to improve the general power factor, but with direct current there is nothing to be gained by using motor-driven compressors rather than direct steam-driven ones.

With regard to the most suitable back pressure for the exhaust steam from the power plant, this depends greatly on the length of pipe lines. The lower the pressure within reason, the better; but one must have sufficient temperature difference between the steam and the liquor to be boiled to get quick heat transference. With very low pressures and large quantities of steam the pipe lines become very expensive and unwieldy, and 20 lb. per square inch initial pressure is certainly much too low for a pipe line half a mile long.

Lifting ejectors are now only used in a few old-fashioned acid works. Perfectly satisfactory pumps for all acids are now available, and even more largely used are blow-eggs, either of the ordinary type, or the Kestner self-acting type.

On the electrical side, it is a fact that, in spite of the best possible arrangements to avoid live metal which can be got at by workpeople, cases do occur from time to time, particularly with lighting fittings; and there are unavoidable trolley wires on electric cranes and runways. I maintain, therefore, that such current must be employed as will not cause a fatal shock to a healthy man who happens to touch a live piece of metal. For equal voltages it is generally admitted that alternating current is much more dangerous than direct current.

Your correspondent's many and elaborate suggestions for getting round the defects of induction motors will not stand a chance when it comes to comparing their first cost and cost of upkeep with direct-current machines and starters. So far from being a snare and a delusion, the pipe-ventilated motor is giving entire satisfaction in many chemical works. In very bad situations, such as acid plants, the enclosed system of pipe ventilation with a cooler in circuit is quite good, but is unnecessary elsewhere.

The statement that one of the principal drives in a chemical works is that of fans, is ludicrous. Except in a few acid plants fan drives do not amount to 5 per cent. of the total. Agitators and grinding mills consume most of the power, and in both these cases large starting torque is often necessary, and not infrequently variable speed on the agitators. The device of putting in larger induction motors than necessary in ordinary running simply results in a bad power factor.

Space forbids me discussing in detail all your correspondent's remarks regarding switch gear, cables and fittings, which are rather outside the scope of the article.

"THE WRITER OF THE ARTICLE."

June 25, 1918.

PAYMENT BY RESULTS.

TO THE EDITOR OF ENGINEERING.

SIR,—I quite agree with the opinions expressed by Mr. Ramsay in his article on "Payment by Results," in your issue of May 31, on page 595 *ante*, and I beg to explain the manner in which we establish the price of a piece manufactured in our Brussels works.

We divide the work into: 1. Time for cleaning the machine-tool and preparing it to start afresh after the removal of a finished piece; 2. Preparing the machine for the following piece; 3. Placing of the piece on the machine; 4. (*a*) Operation, (*b*) operation, &c.

We know by tables the speed of each of our machine-tools, and, in the case of the planing machines, the number of reciprocating motions per minute for the various travels, the cutting speed and feed.

As you will see, we have, in the first place, an extensive division of the work to be done, which results in the calculation, or the appreciation, of very short periods of time; and, in the second place, exact data as to speed, feed, and so forth.

The rate fixer has a printed form which he fills in and hands to the workman with the piece to be machined, and if it happens that the latter cannot work at the speed given, he refers the matter to his foreman, who is able to see whether the man is at fault, or whether an error has been made in the calculation. In this way discussion is avoided.

Moreover, as is recommended in the article, we pay a rate which we never alter, except when an improvement is carried out in the machinery.

If the workman in charge of the piece is the one to improve the method of manufacture, the improvement is reckoned as his due, and we do not reduce the rate. The workman can sell to us his contrivance for the amount saved thereby in the course of one year, and this he does if he leaves our employment.

I think the above may interest your readers.

Yours faithfully,
A. BOLLINCKX.

Hotel du Lac, Vevey, Switzerland, June 11, 1918.

TO THE EDITOR OF ENGINEERING.

SIR,—There are a great many people who, like your correspondent W. J. Grosart, in looking at the question of "payment by results" or the "bonus system of paying for labour" think that the worker should have it all and the employer nothing. To get results in an engineering works you must have organisation, and to get organisation, you have to pay something to get it. If the man working a machine tool has to do a certain amount of preliminary work during which his machine is either idle or cutting wind, he does not get results. But to get results the management devise certain rules and system that remove the preliminary work from the skilled man and much more work is thrown upon the staff and others, which has to be paid for, so that the workman must produce more units in a given time for a price some fraction less per unit to pay for the other labour engaged. There is no penalty in a man taking an increase of, say, 20 per cent. on his wages by the help of others' brains.

Ruskin's dictum would be just as true if put another way, "If we once can get a sufficient quantity of honesty in our workers the organisations of labour is easy, and will develop itself without quarrel or difficulty." Honesty is not an attribute possessed only by the workman.

I am one of those who for over twenty-five years have striven for Ruskin's dictum, and have had considerable success with the premium plan of paying for labour, and I have always found that when you have agreed on the price, the work is done. "You have to pay the inspector"; if you do not, the man will not do that which you have agreed with him to do. He will slip all he can. Now, will Mr. Grosart say which of the two is honest, the captain or the man?

That is the great difficulty you run up against in all the

systems devised to obtain efficiency—to get the desired efficiency one is willing and anxious that the workman shall benefit, and it should be borne in mind that generally the employers do not fix the working prices. Within an hour of writing these lines I have been told by a workman that he had so good a time limit that he dare not charge all his time up to the job; evidently an error had been made, and Ruskin's dictum applied to the workman would be quite in order.

If the workman would look at the matter from a more intelligent and business point of view he would see that all the difference does not go to the employer, and the man gets the larger proportion.

I am, yours truly,
ISAAC ROSS, M.I.Mech.E.

THE DEFINITION OF HARDNESS.

TO THE EDITOR OF ENGINEERING.

SIR,—In your issue of June 7, you published my letter pointing out that Dr. Unwin had apparently not made allowance for the distortion of the sphere, to which letter Dr. Unwin has not replied, although I notice in your issue of the 21st inst. his reply to Mr. Buckingham.

Having been so long engaged on aeronautical engine work, and knowing how common it is to ignore the yield of metals when stressed, I think the matter is of sufficient importance to ask Dr. Unwin to be so good as further to add to the value of his contribution by throwing light on the subject referred to in my letter. The distortion of spheres under stress, particularly as they are used so largely in bearings, is, after all, in itself a matter of some importance.

Yours faithfully,
A. E. PARNACOTT.

Penge-lane, Penge, S.E., June 24, 1918.

COAL ECONOMY AND NATIONAL HEALTH.

TO THE EDITOR OF ENGINEERING.

SIR,—Mr. Orme Bastian's letter on page 666 of your issue of the 14th inst. is interesting. Lord Moulton suggested that instead of gas being charged at "per 1,000 cub. ft." and electric energy at "per Board of Trade unit," both should be sold at "per thermal unit." The public would then know how much heat energy they were buying in either case.

This, Mr. Orme Bastian suggests, would mean that a given number of heat units would cost the consumer the same amount of money, whether supplied in the form of gas or electric energy. It means nothing whatever of the kind, and one wonders what possible object Mr. Bastian can have had in ascribing such foolishness to so eminently sane a person as Lord Moulton. It is as if he said that a proposal to sell in future both by weight two commodities of which one had previously been sold by weight and the other by measure would mean that they must both be sold at the same price per pound.

Having, incidentally, indicated that on the basis of potential heat energy electricity at 1*d.* per unit is five times as costly as gas at 2*s.* 6*d.* per 1,000 cub. ft., Mr. Bastian proceeds to discuss the relative efficiencies of gas and electricity as measured by the useful work done in proportion to the heat units supplied; and having remarked that a statement of his as to the relative net value of heat units purchased in the form of gas and electricity respectively, would be "valueless without some evidence to support it," adduces figures relating to a test in an electric furnace for tempering steel which, according to his assertion, indicated that one heat unit in the form of electric energy was worth 12·5 heat units in the form of gas.

Mr. Bastian gives those figures and no others; and by subsequent references asks the reader to infer that that is a typical comparison of the useful work to be obtained from heat units in domestic heating and cooking, according to whether they are conveyed through a cable or a gas pipe.

I wish to ask him what good purpose he thinks he serves in making a statement the suggested references from which he should know to be absolutely misleading and entirely contrary to practical experience.

If his suggestion had any foundation whatever in the results of using electricity for general heating and cooking, it would not be the easy task it is in fact to point to failure after failure of electricity to compete with gas in the kitchen, nor would it be easy to explain the enormous use of gas-fired furnaces in factories closely connected with the electrical industry.

Yours truly,
W. M. MASON, Secretary.

47, Victoria-street, Westminster, S.W. 1.,
June 22, 1918.

"DUMPING."

TO THE EDITOR OF ENGINEERING.

SIR,—Both of your correspondents, "One Who Does Not Know who is to Pay for Protecting our Industries," and "Timeo Danaos et dona ferentes" appear to have missed the significance of the text of your very valuable article of May 31 on Steel Dumping, viz., that every man, in every country, must be a producer first before he can consume anything. Because he will die if he cannot eat, it is usually assumed that man is a consumer first, although everyone has known and seen from the beginning of time that man must work to live. He must do, or make, something, be a producer of something, before he can eat. The employee sells his labour to live, the employer working with his brains, and often with his hands also, sells the things made. The two of them, capital and labour, are producers first, and are really one indissoluble productive unit, struggling for existence with similar competitive units in this and other countries. This productive unit lives and prospers not by what it can *make*, but by what it can *sell*, in competition with other units making similar articles, and the unit which sells most, prospers most. Industrial life, therefore, is in reality a competition to sell things made, and, obviously, there are two ways of meeting this competition: by producing and selling cheaply, and, by means of taxation, increasing the difficulties of a competing seller. In this country, the employees, Labour, appear to be firmly convinced that producing does not pay. They believe that there is only a limited demand for the things they make, and that the fewer they make, the longer will the job last. They do not realise, yet, that the necessity to live is compelling other men in other countries to produce more and cheaper goods, nor that these men are as firmly convinced that it pays, or will pay, them to sell part of their production below cost until they have killed off competitors who seem to approve of this process of extermination.

Any expense that is incurred between a selling producer and a buying consumer is a tax. Freight is a tax, and it is the experience of merchants that the incidence of this tax is governed by the law of supply and demand. For instance, when there is a big crop of wheat in any one country, it is the invariable experience of exporters that freights to the consuming country rise because there is a demand for ships, but that the price of wheat to the consumer does not; on the contrary, it may fall. The producer of wheat pays the increased tax, or freight, because he cannot live by eating wheat alone, and must sell it to get other things.

In the same way, if a country protects any industry by putting a tax on imported manufactured, or partly-manufactured, goods, the maker of these goods is quite as likely to pay the tax as the buyer. The incidence of the tax depends upon whether the necessity of the seller (producer) to sell is greater than that of the buyer (consumer) to get the goods. The Germans, as you point out, are convinced that it pays them as a nation to keep us out of their markets by prohibitive duties, and to sell their goods in ours below cost in order to stifle our production or selling power, which means eating and living power, seeing we all live by what we can sell.

Whilst the assertion that any tax placed by a buyer (consumer) on any article he imports must be paid by himself is not supported by fact or experience, it is absolutely certain that he pays the whole of every tax he puts upon himself. Income tax is looked upon as payable solely by the employer partner in the productive unit, a delusion which is a creed, fixed and sure, to the labour member. Because the productive (selling) unit in this country is competing in the markets of the world with other producers in other countries of the same things, the price obtainable is determined by the supply of the article, not by its cost in this country, except in so far as higher quality may induce a preference. Taxes, including income tax, are just as much an item in the cost of production as coal or raw material. The employer partner of the unit has to take the price obtainable in the international market, and has to reckon up the cost, including income tax, for he must have a profit or interest on his money, after paying wages, raw material, and taxes, otherwise he cannot live. Therefore, he has to give the employee partner notice that he must stop working unless the cost price can be reduced, either by increasing production or reducing wages, to a figure which will enable him to sell at a profit in the world's market.

Seeing we all live by what we can sell, does "One Who Does Not Know Who Pays for Protecting Our Industries" believe that it pays producers here to tax, which is to increase the cost of, things made by themselves, and to give a bounty, equal to the amount of this tax, which is part cost of manufacture, to the foreign competing seller. His Cobdenite creed might be sound if all countries exchanging commodities agreed to do so absolutely tax-free; it will be equally sound when all countries tax each other equally, for then the tax will be paid sometimes by the producer, sometimes by the consumer, and sometimes partly by both. Seeing every other country taxes our products whilst we admit theirs free, Cobdenism or Free Trade in practice amounts to giving disguised bounties to foreign sellers, a system which reduced to its logical conclusion, means that we shall all be increasingly prosperous the less we produce, and the more we buy. But where is the wherewithal to come from?

In his second letter "One Who Does Not Know" repeats his query "who pays?" and seems to be very much impressed by the natural advantages of other countries where these natural advantages, plus the inherited or acquired industrial superiority of the possessors, exceed ours. Meanwhile they find it necessary to sell us their raw materials because we have other advantages which enable us to convert them into finished saleable manufactured articles cheaper than they can. No one proposes to tax raw materials which we require and cannot raise or grow ourselves. No one objects to iron or copper ores, raw cotton or jute being imported free. Does "One Who Does Not Know" approve of the importation of finished steel, machinery, electric cables, manufactured cotton and jute goods, or wheat which is the farmer's finished article. If he does, the obvious deduction is he believes we shall be most prosperous when our fields are fallow and our factories silent. But seeing we live by what we can sell, shall we not then be dead, or selling our labour or the products thereof in some other land whose inhabitants have realised that they are producers first and consumers afterwards.

PETER SWAN.

June 19, 1918.

TO THE EDITOR OF ENGINEERING.

SIR,—Your correspondent, "One Who Doesn't Know," again asks, Who is to pay for the protection of our industries?—that is, in case we penalise "dumping." The question reveals a woeful ignorance of fiscal economics. May I ask your correspondent who will pay if we so long continue the policy of freely importing bounty-fed and State subsidised goods—German steel, for instance—that our own staple productive industries—iron and steel in this case—are ruined and Germany secures a monopoly? We have paid for this policy in the past by frequently damping-down our furnaces, and compelling our workers to starve or emigrate; by discouraging the investment of capital in our industries; by losing our supremacy in the iron and steel trades. In the light of our past experience, the question who will pay for the protection of our industries against such competition as Germany has offered is childish. Perhaps your correspondent is unaware that our system called Free Trade has been more costly in taxation per head of the population than the Protectionist system of any nation. This was clearly proved by the Prussian Minister of Finance a little while before the war, when he supplied the taxation figures of all the leading countries. And not only is Free Trade more costly than Protection; it is more ineffective. For our high taxes we got no protection against even the worst forms of enemy competition, and no encouragement for our own industries. Our rivals, for their much lighter taxes, got protection from outside competition, and thriving industries. In every branch of productive trade employment increased more rapidly under Protection than under Free Trade. The fact is that we paid for Free Trade for our rivals. The only person in the world who enjoyed Free Trade was the foreigner—mostly the German—doing business in our open market. We were burdened by high taxes at home, in order to provide a free market for our competitors, and our goods had to carry the handicapping weight of foreign tariffs before they could enter a foreign market. We had fettered trade both at home and abroad. Our rivals had lighter taxes at home and a free market here. They had the combined advantages of their own Protection and our Free Trade. We had the combined disadvantages of both policies. That is why our acres went out of cultivation, and our chief manufacturing industries were little better than stagnant, while in other countries agriculture and manufactures prospered side by side. We were the great fool nation. Shall we repeat the folly?

Respectfully yours,
E. T. GOOD.

The Drill Hall, Rotherham, June 24, 1918.

TO THE EDITOR OF ENGINEERING.

SIR,—Surely there is no difficulty in giving a very direct reply to "One Who Doesn't Know." If protection be necessary for the security or well-being of the nation, there is no injustice in asking the nation to pay for it. The real difficulty is not as to who should or will pay, but to decide in any particular case what the true ultimate cost may be, taking all pertinent factors into consideration. When this is done in certain cases the apparent debit turns out to be really a credit, and then protection is clearly profitable to the nation at large. For example, the whole civilised world is now benefitting by the rapid development of the American steel trade which protection rendered possible. Perhaps the following quotation from your issue of March 31, 1916, page 308, may help your correspondent to realise that dumped goods may in the ultimate be very much dearer than the shallow-minded are prone to believe. Speaking at the Institute of Metals, Mr. J. Dewrance said: "Years ago the speaker's laboratory developed into a factory for the production of a certain metallic salt. The manufacture was next taken up in Germany, and from time to time he got full particulars of their methods and processes, which were throughout much inferior to his own. Finally, however, the Germans cut the price below what it cost them to produce, and the speaker decided to close down his works. The next week prices were doubled, and the cost was now twelve times as much as formerly."

I am, yours faithfully,
"DIDYMUS."

THE STABILITY OF AEROPLANES.

TO THE EDITOR OF ENGINEERING.

SIR,—Messrs. Cowley and Levy are right in concluding that "I still miss the point which," they say, "is clear to all my readers"; it appears to be clear to two of them, at any rate. I am quite willing to leave it at that, and to let readers judge between us. If the correspondence leads any engineers to read my article of May 3 out of curiosity, still more if they read it in a critical spirit, I am content.

Yours faithfully,
H. A. WEBB.

Southcote, Blackwater, Hants., June 24, 1918.

THE INDUSTRIAL RECONSTRUCTION COUNCIL.—The work of the Industrial Reconstruction Council is expanding so rapidly that it has been found necessary to secure more adequate office accommodation, and the address of the organisation will, in future, be 2 and 4, Tudor-street, E.C.4. The work has been re-organised and divided into sections superintended by sub-committees. Mr. Ernest J. P. Benn remains chairman and administrative chief, Sir Alexander Roger is in charge of the membership section, Dr. William Garnett and Mr. Emil Davies control meetings, and Sir Herbert Nield, K.C., M.P., is Parliamentary representative. The council is also extending the work of propaganda through other organisations, and is now prepared to send speakers to any societies to lecture or initiate discussions upon the various aspects of the Whitley Report. Applications should be made to the secretary, who would also be glad to supply literature for distribution.

BLAST-FURNACE BEARS.*

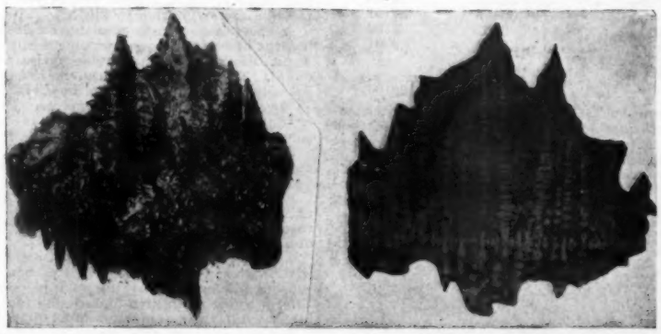
By Dr. J. E. Stead, F.R.S., Vice-President.

(*Concluded from page* 708.)

Section IX.

Iron Phosphide and Iron Carbide in Crystals.—From the conclusions arrived at in Section VIII, it was clear that if a portion of the metal rich in phosphorus is removed in the manner suggested by pressure, the fusible liquid expressed after solidification must be present in some part of the bear itself, and traces of it were actually found in the massive Skinningrove bear, but not in such quantity as one would expect to find.

Mr. Cochrane, however, sent the author a lump of metal taken from the upper central axis of a bear from No. 4 furnace containing a drusy cavity lined with what appeared to be octahedral crystallites of the fir-tree type, rod-like crystals of Fe_3P, and flat plates of Fe_3C.



No. 11.—A crystallite from a drusy cavity in an Ormesby bear. ×5.

No. 12.—The same as 11 after sectioning through the branches, polishing, and heat-tinting.

White = Primary crystallites iron and carbon.
Half-tone variegated = Iron, carbon, phosphorus eutectic.
Black = Iron carbide crystal.

No. 13.—Completely divorced ternary eutectic. Heat-tinted. ×330.
Dark = Fe_3C. Half-tone = Fe_3P.
White = Ferrite.

No. 14.—The binary eutectic Fe—Fe_3P, on its passage from the ternary eutectic towards complete divorcement. Heat-tinted. ×330.
Dark = Fe_3C. Half-tone = Fe_3P.
White = Ferrite.

The fractured surfaces of the metal surrounding this were white, merging into grey. The metal several feet below was columnar and had the following composition, namely :—

	Per Cent.	
Combined carbon	0·91	3·04
Graphite	2·13	per cent.
Silicon	1·13	
Phosphorus	0·078	

The metal from which this was derived contained about 1·5 per cent. phosphorus. The white part of the metal, a little distance above the columnar portion, forming the walls of the drusy cavity, contained :—

	Per Cent.
Combined carbon	3·14
Graphite	traces
Silicon	0·746
Phosphorus	2·910

Naturally one would expect to find metal rich in phosphorus located above the columnar portion, and judging from the above analysis, a portion of it was actually found in that very position, for it contains nearly twice as much phosphorus as normal Ormesby iron.

The drusy cavity must at one time have been filled with metal much richer in phosphorus, for its surface and the surfaces of the octahedral crystallites were coated with the Fe–C–P ternary eutectic, which we know contains about 7 per cent. The character of the fir-tree crystals and crystallites projecting into the cavity are further evidence that the cavity had at one time been filled with a rich phosphorus liquid, for such crystals can only grow in a liquid. Where the liquid finally passed to there was no means of determining; possibly it percolated into contraction porosities.

The fir-tree crystallites, apparently octahedral skeletons, were broken off the walls of the cavity and were crushed to powder for analysis. It was noticed while crushing that portions could not be obtained in powder as they were quite malleable in the cold and became flattened out into thin bright plates. The greater part consisted of powder, which was sieved off; but some of the malleable parts got broken up and passed through the sieve, and a portion of the brittle powder was embedded in the malleable flakes which remained on the sieve. The two parts were weighed and analysed with the following results :—

	Hard Brittle. Per Cent.	Soft and Malleable. Per Cent.
Carbon	2·29	1·090
Manganese	0·05	0·006
Silicon	0·49	0·836
Sulphur	0·26	0·016
Phosphorus	5·75	0·640
Weight ... grammes	24·7	14·0
Phosphorus soluble in dilute acid	1·65	0·32
Iron dissolved in dilute acid	38·25	90·00
Phosphorus in free phosphide	4·10	0·32

The microscope proved that the malleable part was pearlite, and could not contain in reality more than 0·9 per cent. carbon and no free phosphides. The phosphorus in the free phosphides actually present must represent a portion of the hard powder bedded in it during the crushing process. Allowing for this, by calculation we arrive at the probable actual composition of the softer portion. In like manner, a rough estimate of the proportion and composition of the hard part was made. The results are as follow :—

	Hard Part. Per Cent.	Soft Part. Per Cent.
Carbon	2·38	0·90
Manganese	0·05	0·005
Silicon	0·41	0·87
Sulphur	0·27	0·014
Phosphorus	6·32	0·32
Weight ... grammes	23·0	15·6

The pure eutectic of iron, carbon, and phosphorus contains about 2 per cent. carbon and 6·95 per cent. phosphorus. The carbon is in excess of 2 per cent., and it may be safely assumed that the excess represents massive carbide of iron.

One of the crystallites was polished, etched, and heat tinted, and was photographed before and after preparation. It is represented in photographs Nos. 11 and 12. The white parts are the malleable portions, the dark blade on the upper left-hand corner, carbide of iron, and the half-tone parts the ternary eutectic. The foregoing analyses lead to the conclusion that the three constituents are present approximately in the following proportions :—

	Per Cent.
Eutectic of iron, carbon and phosphorus	56·1
Massive carbide of iron	3·6
Soft pearlite	40·3
	100·0

The other crystals, together with a few of the crystallites, were sent to Mr. L. J. Spencer, M.A., F.G.S., of the Mineral Department of the British Museum, and Mr. Spencer has written a report on them, which he presented to the Mineralogical Society in 1915.

As the report is of unique interest, Mr. Spencer has given permission for its publication in the present paper.

CRYSTALS OF IRON PHOSPHIDE (RHABDITE) FROM A BLAST FURNACE.

By L. J. Spencer, M.A., F.G.S.

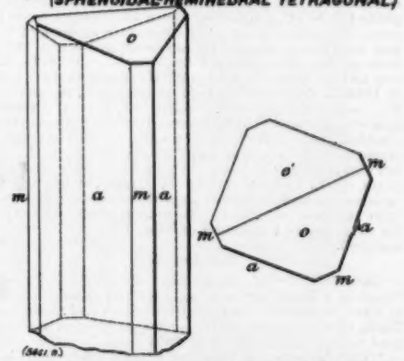
Assistant in the Mineral Department of the British Museum.

[November, 1915.]

The crystals here described were sent by Dr. J. E. Stead, F.R.S., for crystallographic determination. They came from a "bear" or mass of metal weighing about 300 tons that had solidified at the bottom of one of the blast furnaces of Messrs. Cochrane and Co., Limited, at Ormesby Ironworks, Middlesbrough. They are present only in sparing amount in drusy cavities, and are absent in the mass of metal itself. These drusy cavities are lined with "fir-tree crystallites" of metallic iron, which consist of small peg-like crystals grouped in lines along three directions at right angles. Resting on these, and often extending completely across the small spaces, are the bright needles of iron phosphide. The amount of material was unfortunately insufficient for a chemical analysis, but the presence of phosphorus and iron was confirmed: nickel is absent.

Iron phosphide is also present as a coating on the surface of the "fir-tree crystallites," the core of which consists of metallic iron. The cavities also contain a few blade-like crystals of iron carbide; these are tin-white

Fig. 4. CRYSTAL OF IRON PHOSPHIDE. (SPHENOIDAL-HEMIHEDRAL TETRAGONAL)



(sec: a)

with brilliant metallic lustre, strongly magnetic, and very similar in general appearance to the needles of iron phosphide. Inferior measurements on the goniometer suggest that they are distorted cubic crystals flattened parallel to a face of the cube and with octahedral faces on the long edges of the blades.

The needles of iron phosphide are tin-white in colour with a brilliant metallic lustre, and sometimes a yellowish tarnish. They are brittle, and break with a subconchoidal cross fracture. They are strongly magnetic, being readily attracted by a magnetic needle. In length they range from 1 mm. to 3 mm. and in thickness 0·1 mm. to 0·25 mm. They have the form of square prisms truncated on their edges by planes at 45 deg. The faces, however, often vary considerably in relative size: some are absent or visible only on the goniometer as a mere line, whilst others are largely developed, sometimes giving rise to a more or less pronounced platy habit of the crystals. The best goniometric readings in this prism-zone on several crystals were 44 deg. 57 min., 45 deg. 0 min., 45 deg. 2 min., 45 deg. 4 min., &c. The crystals are therefore presumably tetragonal.

Only three crystals with terminal faces were found, each of which shows only two pyramidal faces, as represented in the accompanying Fig. 4. This distribution of faces points to the symmetry being that of the scalenohedral or sphenoidalhemihedral class of the tetragonal system, of which copper-pyrites is a well-known example. It is possible, however, that the class may be the sphenoidal-tetratohedral, but no doubly-terminated crystals have been observed. Etched figures would decide this point; but none could be produced. The

* Paper taken as read at the meeting of the Iron and Steel Institute on May 3, 1918.

best measurement obtained from a terminal face was the angle $m\,o = 63$ deg. 52 min., from which is calculated the axial ratio :

$$a : c = 1 : 10{\cdot}3469.$$

On another crystal $m\,o = 65$ deg. 54 min. The readings oo' on the three crystals were 51 deg. 51 min., 52 deg. 6 min., and 52 deg. 45 min., mean 52 deg. 14 min. ; and the mean of all readings ($m\,o$ and oo') gave $oo' = 52$ deg. 15 min. The only forms present on the crystals are a (100), m (110) and o (111).

Tetragonal crystals of iron phosphide have been previously measured and described by E. Mallard and by C. Hlawatsch. Crystals having the form of a right prism on a square base were prepared artificially by T. Sidot* in 1872 ; whilst still earlier, according to P. Daubrée,† prismatic crystals of undetermined system had been made by Boblique. Mallard's‡ crystals had been formed by the burning of a coal-seam at Commentry in France. They showed the same forms as the crystals now described, except that they were terminated by four pyramidal faces. Hlawatsch's§ crystals were found in a mass of slag and iron in a blast-furnace at Beraun in Bohemia. These again showed the tetragonal forms a (100), m (110) and o (111), but with only two, instead of four, pyramidal faces. Hlawatsch therefore suggested that the crystals belonged to the scalenohedral class.

The few angles that have been measured on the crystals from these three sources are tabulated below ; they are in sufficiently close agreement to establish the identity of the materials.

Although several phosphides of iron have been pre-

Angle.	Mallard (1881).	Hlawatsch (1903).	Spencer.	
			Measured.	Calculated.
$oo' = 111 : \bar{1}11$	—	*52° 10′	52° 14′	52° 16′
$oo = 111 : \bar{1}11$	36° 18′	—	—	36 18
$mo = 110 : 111$	—	—	*63 52	—
$ao = 100 : 111$	*71 56	—	71 46	71 51
Axis c	0.3451	0.3462	—	0·3469

pared in the laboratory, unfortunately the chemical composition of definitely crystallised material has not been satisfactorily determined. Sidot gave the composition as Fe_4P, whilst Mallard's material, analysed by A. Carnot, led to the formula Fe_7P_2. It is not, however, clear from the original descriptions whether these analyses were made on separated tetragonal crystals or on the associated crystalline mass. Dr. J. E. Stead‖ arrived at the composition Fe_3P for crystallised material which showed rhomb-shaped outlines in section.

Iron phosphide has not been observed as a terrestrial mineral, but the frequent presence of iron-nickel phosphide $(Fe,Ni)_3P$, containing about 15 per cent. to 30 per cent. of nickel replacing an equivalent amount of iron, has long been known in meteoric irons and stones, having been first detected by Berzelius in 1832. This was named schreibersite by W. Haidinger in 1847 ; and in 1864 G. Rose described acicular crystals, belonging to the tetragonal system, which he named rhabdite. Schreibersite and rhabdite have since been proved to be identical, although the latter name is still applied to crystals of the acicular habit as distinct from those of the platy habit. Figures of rhabdite crystals have been given by E. Cohen¶ and by E. Hassah,** but without satisfactory measurements capable of direct comparison with those given above. Nevertheless the identity of the artificial and meteoric crystals has been frequently assumed.

Section X.

Carbo-Silicide of Iron and Manganese.—Poulaine found in a drusy cavity an aggregation of large crystals of what proved to be carbo-silicide of iron and manganese. These were described by the author as follows, in a paper read before this Institute in 1901 :—††

"The furnace for some time previously had been employed in the manufacture of rich ferro-manganese. During the Welsh colliers' strike it was damped down, and eventually was blown out. Mr. E. Poulaine, general manager at the Blaina works, who kindly supplied me with the crystals, informed me they were found about 12 ft. below the hearth, and a foot or two lower than the mass of the 'bear' proper. They were found in a cavity of the sandstone foundation of the furnace, into which the liquid metal had entered through some cracks in the stonework, where they eventually crystallised. During its life the furnace made spiegel and ferro-manganese : no silico-spiegel nor ferro-silicon was made.

"The photograph (Fig. 5) was taken after the oxide had been removed and is one-third larger than natural size. Fortunately a few of the complete crystals had their terminal faces ; they were evenly coated with a layer of what appears to be oxide, tenaciously adherent to the metallic surfaces. On digesting in strong acid, this was dissolved away, leaving the faces dull. Portions of the metallic crystals were separated and analysed, with the following results :—

	Per Cent.	After Deducting 5·16 Oxygen, &c. Per Cent.
Manganese	51·75	54·56
Iron	35·76	37·71
Silicon	3·62	3·82
Carbon	3·71	3·91
Oxygen, &c.	5·16	—
	100·00	100·00

"On examining the crystals microscopically, it was noticed that what to the unaided eye appeared to be homogeneous metal was not actually so, as the parts nearest to the surface consisted of mixtures of metal and oxide, hence the large balance left unaccounted for in the analysis of 5·16 per cent.

"In endeavouring to ascertain by calculation if the crystals had any definite chemical composition, it was

FIG. 5.

found that the ratio of the atoms of the metals to those of the metalloids is very nearly—

$$(0{\cdot}6\ Mn\ 0{\cdot}4\ Fe)_7\ (0{\cdot}3\ Si\ 0{\cdot}7\ C)_2$$

"Professor Bauerman is of the opinion that the crystals have a composition sufficiently close to be regarded as the molecule expressed by the formula $(FeMn)_3\ (SiC)$.

"By calculation it is found that these compounds would have the following percentage composition :

	$(MnFe)_7\ (SiC)_2$ Per Cent.	$(MnFe)_2\ (SiC)_3$ Per Cent.
Manganese ...	54·74	54·14
Iron	37·21	36·65
Silicon	4·03	4·60
Carbon	4·03	4·60 "

These crystals of double carbon and silicide of iron, it is believed, have not been seen before or since they were found by Mr. Poulaine.

That the silico-carbides could exist either in the independent state or in silico-ferro-manganese was a revelation, and leads one to believe that the compound may be present in silico-carbon alloys.

Section XI.

Unique Specimens for Microscopists.—Just as slow cooling of liquid metals during solidification leads to the formation of crystals of large dimensions, so the slow cooling of the same metals after solidification favours the formation of splendid specimens of lamellar and spheroidal pearlite. One also obtains in some bears both the binary eutectic of iron and phosphorus and the ternary eutectic of iron, carbon and phosphorus, with these divorced complexes in the condition most easily studied under low powers of the microscope. Examples of them are given in photos Nos. 13 and 14.

There are, as has previously been referred to, more or less massive segregations of mixed sulphides and other materials—graphite in thick curved plates, in some of which the crystalline characters can be detected, and graphite in the spheroidal condition.

Examples of many of these were illustrated in a previous paper, and others are given in this. Indeed, there is no more fertile source of specimens for metallographers than the bears of blast furnaces.

As the author has a considerable quantity of specimens in the rough state, he will be glad to present on application portions of each to chemists in works where pig-iron is produced.

Final Summary.

The following is a summary of the chief points of interest :—

1. Spheroidal form of graphite, probably built up of aggregations of fine laminæ.

2. Proof is given that sulphide of iron and sulphide of manganese crystallise together in many proportions, in mixed crystals or homogeneous solid solutions, and that considerable accumulations of sulphides occur in parts of bears, one of which contained two-thirds of its weight of almost pure MnS.

3. The discovery of a considerable quantity of a mixture containing about 40 per cent. by weight of dark blue cubic crystals, proved by analysis to have a composition approximating to $Ti(CN)_2$.

4. Proof that strongly oxidising conditions exist in the hearths of blast furnaces, which are sufficient to decarburise completely considerable quantities of the pig metal. The decarburised iron is found in part very coarsely crystalline, yielding cleavage faces on fracturing as large as 1¼ in. to 2 in. across. Other parts are crystallised in columns 6 in. to 8 in. in length, and each column consists of a single ferrite crystal.

5. The discovery of an immense number of crystals, more or less idiomorphic, of iron phosphide, Fe_3P, in the body of the columnar ferrite crystals.

6. Discovery of independent and idiomorphic crystals of iron phosphide resembling rhabdite in character, together with crystals of iron carbide in a drusy cavity of an Ormesby bear.

7. Proof, more fully described in a previous paper, that iron manganese silicon and carbon formed homogeneous idiomorphic crystals of iron manganese carbo-silicide below the hearth of a Blaina furnace which had been used in the manufacture of ferro-manganese.

Before terminating this paper, let it not be concluded that the subject of furnace bears, and what they teach us, has been exhausted ; indeed each bear opened out has contributed something new and of great interest, and it is most important that every bear that is broken up in future should be submitted to careful examination.

The changes that have occurred in the brick linings and in the character of the siliceous substances have not been studied at all, and it is quite possible that other new substances may yet be discovered.

Without the active co-operation of the manufacturers of pig-iron and their assistants, even this preliminary paper would have been impossible, and the assistance given in that direction is acknowledged with gratitude.

Some of the names have been mentioned in the text, but others also have assisted : the complete list is a long one, and includes the following gentlemen : Mr. T. C. Hutchinson and his chemist, Mr. F. Bainbridge, of the Skinningrove Iron Company ; Mr. A. O. Cochrane and his chemist, Mr. G. A. Alder, of the Ormesby Iron Works Middlesbrough ; Mr. G. Ritchie, general manager, and his chemist, Mr. D. Sillars, and Mr. Outhwaite, his blast-furnace manager ; Mr. F. M. Percy, of the Wigan Coal and Iron Company ; Mr. E. W. Jackson, Mr. A. Scholes and Mr. T. H. Bellwood, and, last but not least, Mr. L. J. Spencer, of the mineralogical department of the British Museum, South Kensington, who has on this and many other occasions rendered valuable advice and assistance in classifying the many materials submitted to him.

* T. Sidot, "Production d'un Phosphure de fer Cristallisé," *Comptes Rendus*, Acad. Sci., Paris, 1872, vol. lxxiv, page 1,425.

† P. Daubrée, "Observations Relatives au Phosphure de fer Cristallisé Obtenu par M. Sidot," *ibid.*, page 1,427. Boblique, *Bull. Soc. Chim.*, Paris, 1866, vol. v, page 248.

‡ E. Mallard, "Sur la Production d'un Phosphure de fer Cristallisé et du Feldspath Anorthite dans des Incendies des Houillères de Commentry," *Comptes Rendus*, Acad. Sci., Paris, 1881, vol. xcii, page 933 ; *Bull. Soc. Min. France*, 1881, vol. iv., page 230.

§ C. Hlawatsch, "Zwei Krystallisierte Hüttenprodukte von Beraun," *Min. Petr. Mitt.* (Tschermak), 1903, vol. xxii, page 497.

‖ J. E. Stead, "Iron and Phosphorus," Journal of the Iron and Steel Institute, 1900, No. II, page 79, Plate IV, Fig. 5. Similar outlines would be given by change sections of the tetragonal crystals described above.

¶ E. Cohen and E. Weinschenk, "Meteoreisen-Studien," *Ann. k. k. naturhist. Hofmuseums*, Wien, 1891, vol. vi, page 139. E. Cohen, "Meteoreisen-Studien, III," *ibid.*, 1894, vol. ix, page 108. E. Cohen, "Meteoritenkunde," Stuttgart, 1894, pages 125 to 128.

** E. Hassah and O. A. Derby, "Estudo Sobre o Meteorito de Bendigó," *Archivos do Museu Nacional do Rio de Janeiro*, 1896, vol. ix, page 171.

†† Journal of the Iron and Steel Institute, 1901 No. I.

AN AUTOMATIC HYDROELECTRIC PLANT.

By Mr. J. M. Drabelle and Mr. L. B. Bonnett.

On October 2 there was placed in operation at Cedar Rapids, Iowa, the automatic hydro-electric plant of the Iowa Railway and Light Company. This plant represents a further development of the automatic substation first described in a paper by Messrs. Allen and Taylor in the American Institution of Electrical Engineers' Transactions, vol. xxxiv., Part 2, page 1,801.

The station operates with no attendant and the different generating units start or stop, depending on the flow of the river, or can be started and kept running by remote control from the main steam station, as described in detail later.

The building is 112 ft. (34·13 m.) long, 41 ft. (12·49 m.) wide, and has a depth to rock bottom at the bottom of the draught tubes of 37 ft. (11·27 m.). The substructure is of concrete ; the superstructure is 30 ft. (9·14 m.) high above the water table of the building and is constructed of Bedford limestone. The interior of the building is finished in yellow brick and the floor in red tile. There are installed three 500-k.v.a. 80 per cent. power factor, 60-cycle, two-phase, 2,300-volt, 60-r.p.m. generators, of the vertical type. They are driven by water wheels rated 540 brake horse-power, 60 r.p.m. under a 10-ft. (3 m.) head, the operating head varying from 8 ft. (2·43 m.) to 11 ft. (3·35 m.). The runners are of the Francis type, having a diameter of 171 in. (4·33 m.). The rotating element is supported by a thrust bearing at the top, supplied with oil by a pump driven from the generator shaft.

The dam consists of nine spillway sections, each 60 ft. (18·28 m.) long with automatic flashboards, the total overall length being 600 ft. (182·88 m.). The dam is shown in Fig. 1.

There are two General Electric induction motor-driven

* Paper read before the American Institution of Electrical Engineers.

exciter sets rated 100 kw. 125 volts, each capable of carrying the entire excitation of the total development, namely, that of four generators. The motors are rated 150 h.p., 2,300 volts, two-phase, 60 cycle, 1,200 r.p.m., and are designed to be started by the application of full voltage at standstill.

The plant (Fig. 2) is designed to operate in parallel with the 19,000-kw. steam turbo-generating station of the Iowa Railway and Light Company, the steam plant being located at a distance of 3,300 ft. (1,005·84 m.) from the hydro-electric plant. The stations are tied together by one underground line consisting of two 600,000-cir. mil, two-conductor, concentric, 7,500-volt, varnished cambric, lead-covered cables.

The different generating units may be started and stopped either automatically, depending on the rise or fall of the water-level in the river; or by remote control from the steam station when the capacity is needed. To accomplish the latter, a bench-board section, shown in Fig. 5, page 738, was installed in the steam plant. On this, for each generator, there are three single-throw prevents overshooting by quickly stopping the motor after the power supply is interrupted. Each gate mechanism is equipped with a contact-making device operating indicating lamps on the benchboard at the Sixth-street station, showing the exact amount of gate opening.

The correct sequence of operations in the control of each generator is obtained by properly-placed segments on the drum of a controller which is driven by a single-phase 1-h.p. repulsion-type motor. This controller definitely determines the proper time spacing between the different steps of starting the unit and connecting its generator to the bus. One of these is shown in Fig. 3.

The contactor equipment and protective relays are mounted in cabinets. For controlling the exciter sets, two oil-immersed contactors are used, also a double-throw, triple-pole switch, which connects either one or the other of the exciters to the exciter bus. The middle blade of this switch selects the proper contact for starting the exciter set which is connected to the that with full gate opening normal load cannot be obtained, the generator, due to its high excitation, takes care of part of the wattless kilovolt-amperes of the system. The speed and voltage are, of course, determined by the steam turbine generators.

Details of Operation.—Detailed operation of this automatic equipment is as follows, referring to the wiring diagram, Fig. 5.

Connected to the 2,300-volt bus there are two small transformers stepping down to 220 volts, two-phase, for an operating bus. One phase is taken from this bus through the double-pole switch No. 29, for controlling the contactors of each generator equipment. In the line between these transformers and the 220-volt bus there is an emergency throwover switch, which in case of failure of voltage on either phase is thrown over by a spring to a separate source of power brought in from the other station.

The closing of float switch No. 1, as shown on the right-hand side of the drawing, or control button No. 3 in the steam station, closes contactor No. 4 provided that

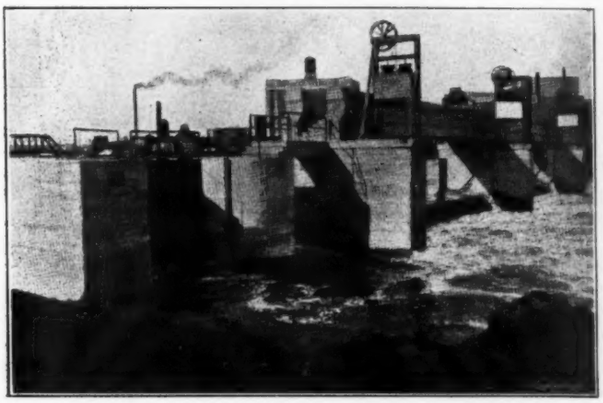


FIG 1. LOCKS ON CEDAR RIVER AT CEDAR RAPIDS.

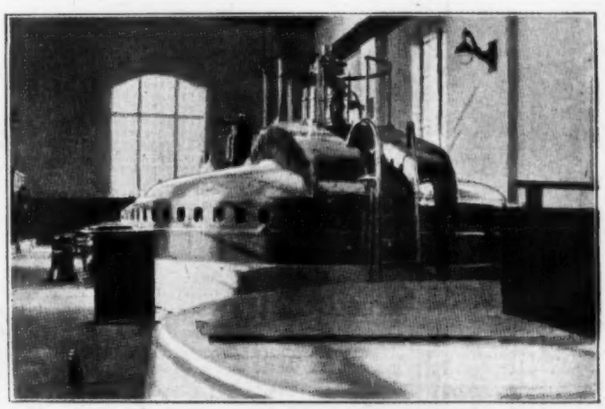


FIG. 2. INTERIOR OF STATION.

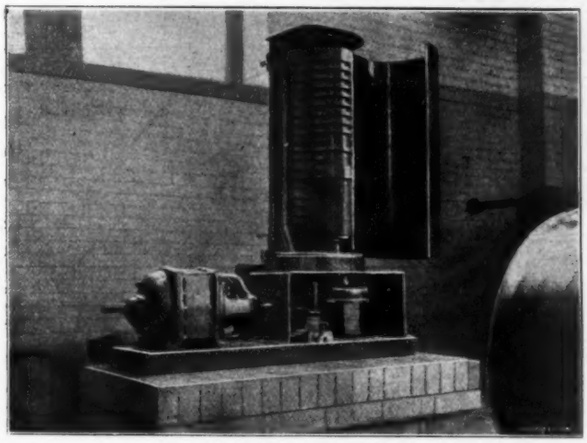


FIG. 3. DRUM CONTROLLER.

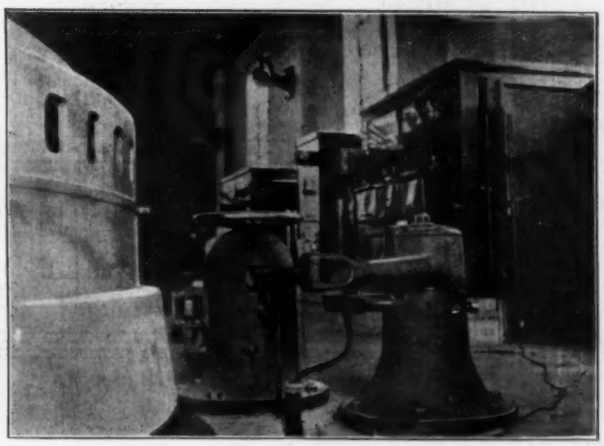


FIG. 4. GATE CONTROL.

and one double-throw control buttons, the purpose of which will be explained later. All control wires between the stations are bunched in a multi-conductor, lead-covered cable consisting of 50 No. 12 and 4 No. 4 B. and S. rubber-covered wires.

The same bench-board contains for each generator an indicating ammeter (150-ampere scale) and wattmeter (600-kw. scale), there being no instruments in the hydro-electric plant. The leads for these meters from the current transformers in the hydro-electric plant are bunched in an eleven conductor, No. 4, lead-covered cable. These leads are wired through calibrating terminals at the hydro-electric plant so that portable meters can be wired in if desired at any time. The lower row of instruments on the benchboard is a totalising equipment, reading the total incoming power from the hydro-electric plant. This consists of two ammeters, a power factor indicator, an indicating wattmeter, a curve-drawing wattmeter and a watt-hour meter.

The water-wheel gates are not supplied with the usual hydraulic governor; but, instead, the opening and closing of the gates is obtained by a 5-h.p. induction motor through suitable gearing (Fig. 4). The gear ratio is such that it requires 25 seconds for the gates to open completely, starting from rest in the closed position. The motor is equipped with a solenoid brake which releases when voltage is applied to the motor. This excitation bus. At the top of the cabinet there is a small induction motor. This carries a centrifugal device on the end of the shaft which in case of frequency of the system rises to 64 cycles, will open, and shut down the plant, thereby preventing runaway.

The units have individual float switches set for slightly different levels. If the water rises to a certain level it closes the float switch of the first unit, and that machine is started and put into service. If the flow of the river is such that the water continues to rise the second float switch closes, starting the second machine. The third switch is set still higher. The machines are shut down in the reverse order as the water-level falls.

In general the sequence of operation of each generator is as follows: The closing of the float switch or the proper remote-control button in the steam station, starts the exciter set (provided it has not already been started with another generator), and opens the water-wheel gate. When the generator comes up nearly to synchronous speed it is connected to the bus without field but in series with a 20 per cent. reactance. A weak field is then applied, pulling the machine into synchronism. The field is then strengthened to full field, the reactance short circuited and the water-wheel gates opened to carry full load on the unit.

The generators operate with a fixed excitation adjusted for normal full-load value. If the water-level is so low control button No. 2 is also closed. This energises segment No. 14 of the controller. Segment No. 17 is in contact with its finger and a circuit is completed through the coil of contactor No. 6, which starts the motor driving the drum controller. A circuit is also made at No. 16 through the contacts of relay No. 41, which is not energised, through the coil of the contactor No. 5, through the contacts of relay E, the inverse-time relays No. 5 and the thermostat relay No. 10. The thermostat relay is connected across one phase of the control circuit and is of course, picked up if all the thermostats are closed, indicating that there is no overheating. Relay E is connected across the other phase and is picked up unless the frequency of the bus exceeds 64 cycles. Contactor No. 5 now closes energising segment No. 1 of the controller. A circuit is now made through segment No. 2 picking up relay No. 42. Either one or the other of the two exciters sets can be started, depending on whether the switch K is closed up or down. The picking up of relay No. 42 completes the circuit through switches No. 28, which are closed, through the coil of contactor G, throwing full 2,300 volts on the stator of the induction motor.

Contactor No. 43, with its coil across the armature of the exciter, short circuits with its contacts the field rheostat until the exciter voltage is built up to 75 volts or 80 volts. The set comes up to speed and the voltage

AUTOMATIC HYDRO-ELECTRIC POWER STATION AT CEDAR RAPIDS, IOWA, U.S.A.; WIRING DIAGRAM.

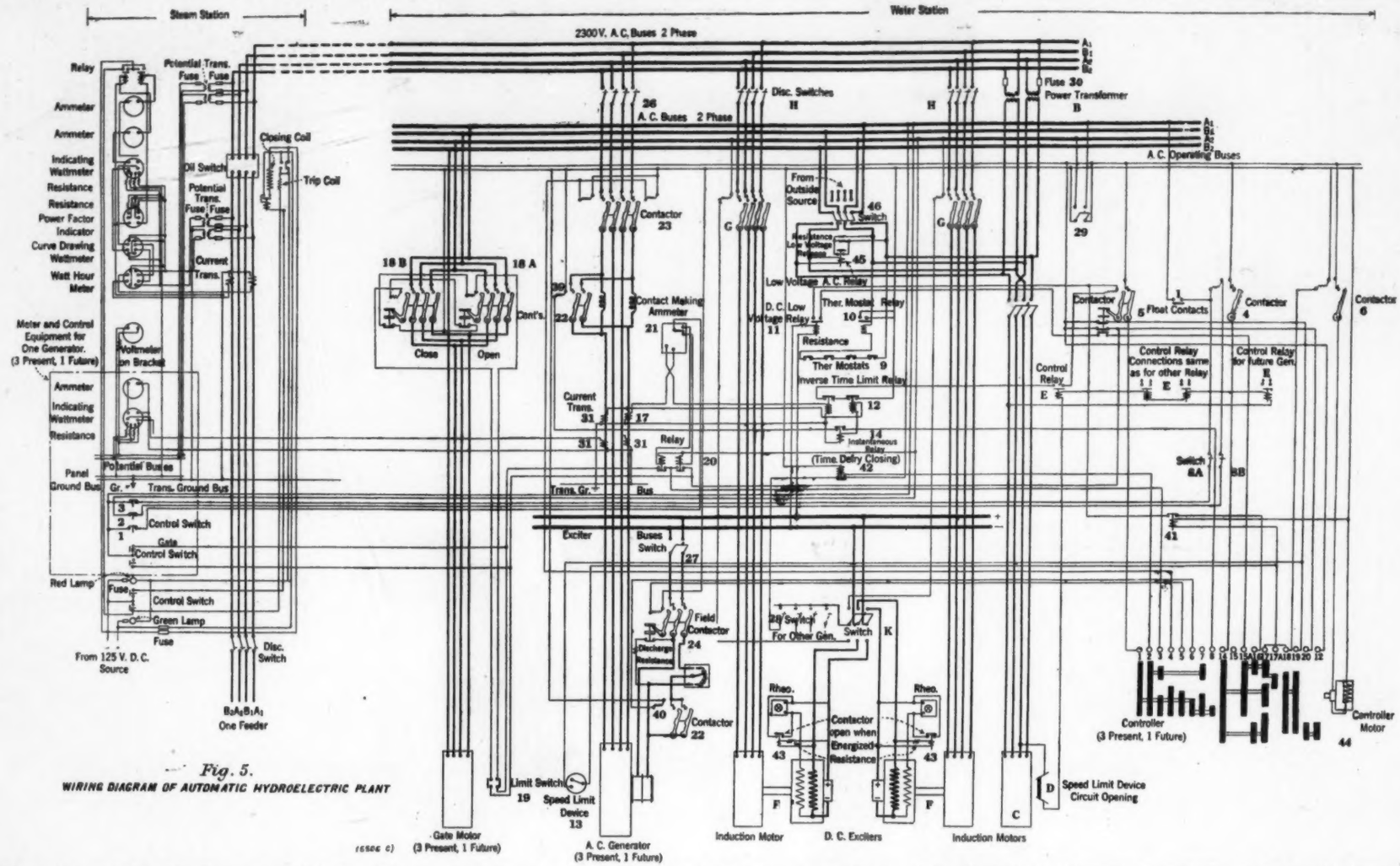


Fig. 5.
WIRING DIAGRAM OF AUTOMATIC HYDROELECTRIC PLANT

up to normal very quickly and the direct-current voltage relay No. 11 picks up. The holding circuit of contactor No. 5 is now closed through this low-voltage relay No. 11, the lower interlock of contactor No. 5 and through segment No. 15 A, so that No. 5 stays closed after No. 16 has left contact unless the exciter voltage drops.

In the meantime, the controller has been rotating and a circuit is made through finger No. 3 to the middle of point of relay No. 20. As the generator is not connected to the line there is no current flowing in the contact-making ammeter No. 21 and its contacts are closed in the up position. If No. 1 button in the steam station is closed the left-hand side of relay No. 20 is picked up. The energising of finger No. 3, therefore, completes the circuit through the coil of contactor No. 18 A, which starts the gate motor in the proper direction for opening the gate of the water wheel. Finger No. 3 is in contact a definite length of time, which is sufficient to give a gate opening on the water wheel of such amount that the no-load constant speed would be about 65 r.p.m. or 70 r.p.m.

The controller motor has been receiving its energy through contact No. 6 held closed by finger No. 17. This finger next comes to the break in its segment and the controller stops in this position, waiting for the generator to come up to speed. On each generator there is a centrifugal device No. 13, set to close at about 55 r.p.m., that is, 5 r.p.m., below normal. When this switch closes, a connection is made from finger No. 17 A to No. 19 and through the controller to No. 18 to contactor No. 6, starting the controller again.

The gate opening is such that the generator is slowly rising in speed, so that by the time the segment No. 4 on the controller comes into contact, the speed is approximately normal. This segment closes contactor No. 23 connecting the generator to the bus without field and with a reactance in series. Finger No. 5 next closes the field contactor No. 24 putting a weak field on the generator and pulling it into synchronism. Finger No. 6 then closes contactor No. 40, short circuiting a part of the field rheostat, thus strengthening the field to full normal value. Finger No. 8 closes contactor No. 39, short circuiting the reactance. In the meantime finger No. 3 has come into contact again and the contact-making ammeter No. 21 opens the gate until the current of the generator is up to normal value.

The generator is now properly connected to the bus and carrying full load. Finger No. 17 comes to the second break in its segment and controller stops in the full running position.

The equipment can be shut down in several different ways. If the pond-level falls, due to the fact that the demand for water is greater than the flow of the river; float switch No. 1 will open. If it is desired that the steam station shut down and start from the water-level, button No. 4 will be open and the opening of both this

button and the float switch will trip contactor No. 4. If it is desired to shut down any generator and prevent its starting again, button No. 2 in the steam station should be opened, thus also tripping contactor No. 4. This de-energises segment No. 14 of the controller, which in turn drops out contactor No. 5. This de-energises segment No. 1 and drops out all other contactors connecting the machine to the bus. When contactor No. 5 drops out, the upper interlock makes a circuit through segments No. 19 and No. 18, picking up contactor No. 6 and running the controller to the off position. The middle interlock of contactor No. 5 is also closed, energising contactor No. 18 B and closing the water-wheel gate. As the controller rotates to the off position fingers Nos. 20 and 21 are bridged. These contactors are in parallel with the middle interlock on contactor No. 5 to give additional contact surface.

Connected to the operating bus is a 1-h.p. two-phase motor driving a speed-limit device which opens its contact when the speed exceeds 64 cycles. If for any reason, the hydro-electric plant becomes separated from the steam station, the generators will, of course, speed up, increasing the frequency of the bus. This, in turn, will trip the speed-limit device D, dropping out the four relays E, which in turn drop contactors No. 5 on all generators. This drops out all other contactors, and as the bus voltage then drops to zero the automatic throw-over switch No. 46 connects a separate source of power to the control bus, thus furnishing energy for closing the gates of the water wheels to shut down. The wiring is so arranged that the relays E and No. 10 are connected outside this throw-over switch so that the generators cannot be started until the main cable between the station is re-energised.

If for any reason the generators have gone above speed and the main tie cable has been re-energised, relay No. 41, which is picked up whenever the centrifugal switch on the generator is closed, prevents the picking up of contactor No. 5, until the speed of the generator has dropped to a value somewhat below normal. This prevents the generator from being thrown on the line again when running at a considerable speed above normal.

The foregoing description covers only one generator; but also applies equally to the other generators. Each controller has a relay No. 42 so that the exciter can be started from any controller; that is, any generator can be started first and its controller starts the exciter.

The steam station is equipped with control buttons so that, if desired, the gate opening, and therefore the load on the hydro-electric generators, can be controlled from that place. The ammeter control is cut out by opening button No. 1.

Tests.—A considerable number of tests were taken to determine what would happen in the automatic equipment in case of incorrect operation of the control buttons, or failure of some part to operate correctly.

First, one of the No. 1 control buttons was opened and the load on the generator controlled by hand. It was found impossible to overload the generator, even with the gate opening to the full amount allowed by its limit switch. Button No. 1 was then closed, putting the ammeter again in control, and at the same time the operator tried to control the load from the gate control buttons. It was found that he could increase or decrease the load as desired; but when the hand control button was released the ammeter returned the load to the proper amount determined by its setting.

Buttons Nos. 2 and 3 were opened and immediately reclosed. The opening of these buttons tripped out all contactors and started the gate motor closing. The reclosing of the buttons caused the controller to rotate, but since the generator was running at normal speed or a little above, relay No. 41 was held up and contactor No. 5 could, therefore, not pick up. This prevented any other contactors from closing. The controller made about 1½ revolutions before the generator speed dropped so that relay No. 41 could reset. The next time around the controller picked up contactor No. 5, and went through the usual sequence of starting. This proved that if the operator accidentally opened one of these buttons and immediately closed it again, the generator would not be thrown immediately back on the bus, but would go through its proper sequence of operations.

In the steam station there is a voltmeter connected on the hydro-electric side of the oil switch. We next tripped this oil switch and found that the voltage dropped to zero in about 2 seconds, indicating that in this time the contactors in the hydro-electric plant had all tripped out, thus clearing the generators from the bus. Upon tripping of this oil switch the generators lost their load and tended to run away. Within the 2 seconds mentioned the speed-limit device trips relay E at 64 cycles and all contactors drop out. The automatic throw-over control switch connects the separate source of power to the control bus and the dropping out of contactors No. 5 closes the water-wheel gates. We did not read the maximum speed reached, but it was very apparent from watching the machines that the speed rose to not more than 20 per cent to 25 per cent above normal. The action of the gate is quite rapid and the inertia of the machines is such that the gates close before the wheels have time to accelerate seriously.

With the generator running under load we shut down the exciter set. The armature current of the generator immediately increased and the contact-making ammeter started to close the gate. The contactors connecting the generator to the bus dropped out, due to the tripping of the direct-current, low-voltage relay No. 11, which dropped because of the failure of the exciter voltage. The generator, after loss of field, broke from synchronism and tended to run above speed, but the contact-making ammeter had already closed the gate far enough to prevent serious overspeed, and the drop out of the contactors completed the closing.

Since the hydro-electric plant has been put into regular operation, the exciter in the main steam generator station failed one day. The load on the system, of course, was much greater than the hydro-electric plant could carry by itself, so that this plant should shut itself down and clear from the steam plant. As soon as the exciter voltage in the steam station began to drop, the current of the hydro-electric generators, of course, rapidly rose and the contact-making ammeters started the closing of the water-wheel gates. Before the voltage dropped too low, the ammeters had almost completed the closing of the gates. All contactors dropped out because of low voltage disconnecting the generators from the bus. The hydro-electric plant was ready to start again upon return of voltage on the tie cable between the two plants.

An oscillogram has been taken of the starting conditions and shows the different contactors operated. The first part of the film shows the generator connected to the line without field. Next a weak field is applied, pulling the machine into step. The field is then strengthened to normal. There now seems to be a tendency for the current to pulsate, presumably caused by the heavy 20 per cent. reactance in series with the machine. The short circuiting of this reactance quickly steadies the current into a stable condition. The wave shown at the end of the film is something less than normal load, as the contact-making ammeter, the day this film was taken, was set for holding less than full load. The time from the throwing on the line to the short-circuiting of the reactance is about 11 seconds.

Although the generators are slow speed and have considerable inertia, only 30 seconds are required from beginning of the opening of the gate until the generator is connected to the bus, with a reactance short circuited. Within 45 seconds, the generator is carrying full load. In spite of the speed with which these generators are connected to the bus, there is no serious mechanical jar perceptible.

The plant has now been in operation from October 2 until the present, and so far, no troubles, other than the small ones which always go with any new development, have been experienced, and these have all been of a very minor nature. The changes that have been made, consist essentially of substituting heavier and more reliable relays in one or two points on the control system, and the expectations and hopes of those who have worked on this development have been more than realised. The plant has successfully withstood short circuits, exciter failures in the steam plant, low water and high water, and all of the tests that those in charge of the work could conceive of, wrong operations being brought about artificially. It has also been operated by the regular operating force at the steam plant, and there has been no occasion to keep men, nor have they been kept in the hydro-electric plant to watch its operation.

The automatic development, if it means anything at all, means that it will now be possible to develop a large number of small low-head plants and tie them in on a high-tension system, leaving their operation entirely to the float switch and voltage relays. If there is voltage on all three phases of the high-tension line and water for the turbines, they will start up and go on the line without wrecking themselves or disturbing the operation of the rest of the system. In these days of scarcity of coal and scarcity of labour, together with its high price, the utilisation of our water power is of national importance, for, every pound of coal that can be saved by the water of our rivers is just that much more that can be used by our country for the successful prosecution of the war.

With the elimination of the excessive labour cost of operation of a small plant, many water-power sites are capable of development as a paying investment.

As this paper goes to press, the station has been in operation about seven months. Some notes as to experience with it might be of interest. During this time, the total flow of the river has been used at all times, and a toll of approximately 3,000,000 kw.-hours has been fed into the system. There have, of course, been a few failures to start, as no automatic apparatus can be absolutely infallible. The source of such failures has been easily found and corrected. In this connection the equipment is designed to shut down in case of abnormal conditions, so that all the machines will be protected against injury. It is also of interest to note that owing to the pressure of other work and the shortage of help, this generating station ran continually for ten weeks, with no attention to automatic equipment of any kind. Of course, a more frequent inspection and cleaning of the contacts should be made in order to keep the equipment in the best of condition. There have been several cases of exciter trouble at the main steam station, which resulted in a complete shut down. As soon as bus voltage was restored, the automatic equipment put the hydro-electric plant back on the line without attention of any kind, and with no damage or injury to any of the machines. The expense for operators is a large per cent. of the total cost of the operation of small hydro-electric plants. Many plants have considerable trouble in keeping their operating forces, particularly in these days of shortage of labour. With the present high price of coal and the shortage of labour, many small water powers might be developed with a profit as auxiliary plants on a fairly large steam generating system.

AIR MINISTRY, ENGINEERING.—Mr. Frederick Palmer, C.I.E., M.Inst.C.E., partner in the firm of Messrs. Rendel, Palmer and Tritton, consulting engineers, has accepted the invitation of the Secretary of State for the Royal Air Force to act as Honorary Adviser to the Air Ministry in engineering questions associated with the Department of Works and Buildings.

ROYAL METEOROLOGICAL SOCIETY.

THE last monthly meeting of this Society for the present session was held on Wednesday, the 19th inst., at the Society's Rooms, 70, Victoria-street, Westminster, Sir Napier Shaw, F.R.S., President, in the chair. Dr. S. Chapman, F.R.A.S., read a paper, entitled "*The Lunar Atmospheric Tide at Greenwich*, 1854–1917." The tidal forces due to the moon affect the aerial as well as the fluid ocean, and the lunar atmospheric tide is manifested by a periodic variation in the height of the barometer having two maxima and two minima (high and low tide), in the course of a lunar day. This variation is much smaller than the solar semi-diurnal barometric variation, which is not a simple solar tidal effect. The minute lunar variation, however, can be detected with ease in the records of tropical observatories, where the irregular fluctuations of pressure are small. Attempts to determine it in the records of European observatories have been made, but hitherto without success. By treating hourly observations of "quiet" days only, on which the barometric range did not exceed 0·1 in., and by abstracting the solar variation, the lunar atmospheric tide at Greenwich has now been ascertained. Its total amplitude is less than 0·001 in., the harmonic formula being 0·00036 sin (2*t* + 114 deg.)in., where it represents lunar time measured, at the rate of 360 deg. per lunar day, from the epoch of upper transit. A comparison with the variation at Batavia (lat. 6 deg. S.), viz., 0·00256 sin (2*t* + 65 deg.) in., suggests that the amplitude varies as the fourth power of the cosine of latitude, and that the phase also varies with latitude.

A paper by Mr. Miller Christy was also read, entitled "*The Audibility of the Gunfire on the Continent at Chignal St. James, near Chelmsford, during* 1917," in which the author continues his series of observations of the sound of gunfire commenced in 1915, and published by the Society in 1916. In the present paper the record is confined entirely to Mr. Miller Christy's observations at Chignal St. James. Mr. Christy considers that the most interesting point in connection with his observations is the fact that there is, apparently (1) a regular and well-defined season or period during which the gunfire is usually audible with ease, and that this is followed by (2) a longer season or period during which the gunfire is seldom or never heard. The following are the earliest and latest dates of the sound of the gunfire on the Continent, as heard at Chignal St. James during the three years 1915–1917:—

1915—From about May 1 to about August 31 = 17 weeks, 3 days.
1916—From about May 1 to about August 15 = 15 weeks 1 day.
1917—From about April 22 to about September 6 = 19 weeks 4 days.

Mr. F. J. W. Whipple, F.R.Met.Soc., also contributed a paper, entitled "*Seasonal Variation in the Audibility of Gunfire.*" Mr. Miller Christy's observations indicate that in Essex, Continental gunfire is only heard during the summer months. On the other hand, evidence collected by W. Brand, and published in the *Meteorologische Zeitschrift*, in February, 1917, indicates that in Germany, at places 100 km. or more from the firing line, such sounds are only heard during the winter. Thus, it appears that in summer the outer zone of audibility lies to the west of the source of sound, in winter to the east. No theory hitherto put forward in explanation of the existence of the outer zone of audibility is in accord with this generalisation.

TRADING WITH THE ENEMY ACT.—The Controller of the Foreign Trade Department has issued a new list (No. 57) of additions to the Statutory List of firms of enemy nationality or enemy association with whom persons in the United Kingdom are forbidden to trade. Copies of this list can be obtained at a trifling cost from the Superintendent of Publications, H.M. Stationery Office, Imperial House, Kingsway, W.C.

THE ROYAL SANITARY INSTITUTE.—Men discharged from the Navy or Army on account of wounds, disease, or other disablement contracted during naval or military service, are allowed to enter for the Institute's course of lectures and for the Institute's examinations at half fees, provided that their disability is not such as to prevent them carrying out the duties of the office to which the examination applies. Sailors' or soldiers' widows whose husbands have been killed or have died during the present war, or sailors' or soldiers' wives whose husbands have been permanently disabled during the present war, are admitted to the courses of lectures, or the examinations of the Institute, at two-thirds of the ordinary fees.

CO-ORDINATION OF RESEARCH IN WORKS AND LABORATORIES.—The council of the Institution of Electrical Engineers are prepared to receive papers on the subject of "The Co-ordination of Research in Works and Laboratories," with a view to the paper being read and discussed at one of the ordinary meetings of the Institution in London, and also before one or more of the local sections. Papers should not exceed 15,000 to 20,000 words in length, and the council are prepared to award a special premium of 25*l.* to the author of the paper which in their judgment best fulfils the objects of the discussion, provided such paper reaches the standard aimed at by the council. Papers should be sent to the Secretary of the Institution not later than November 4, 1918. It is the intention of the council to publish the selected paper (which will become the property of the Institution) in the Journal, together with the discussion. Competitors intending to submit papers are invited to communicate with the secretary.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

SELECTED ABSTRACTS OF RECENT PUBLISHED SPECIFICATIONS UNDER THE ACT OF 1907.

The number of views given in the Specification Drawings is stated in each case; where none is mentioned the Specification is not illustrated.

Where inventions are communicated from abroad, the Names, &c. of the Communicators are given in italics.

Copies of Specifications may be obtained at the Patent Office, Sales Branch, 25, Southampton Buildings, Chancery-lane, W.C., at the uniform price of 6d.

The date of the advertisement of the acceptance of a Complete Specification is, in each case, given after the abstract, unless the Patent has been sealed, when the word "Sealed" is appended.

Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any grounds mentioned in the Act.

ELECTRICAL APPARATUS.

114,968. Osram-Robertson Lamp Works, Limited, and O. Durdle, Hammersmith, London. Wireless Telegraphy. (3 *Figs.*) September 11, 1917.—According to the invention, the anode for an ionic tube is formed of cloth woven from wire of a selected highly-refractory metal or alloy, preferably molybdenum or an alloy thereof; the cloth being woven as closely as practicable, from wire of fine gauge (say, about 0·2 mm. diam.), so as to present a substantially continuous surface virtually devoid of apertures capable of affording passage to rays falling normally upon it. The anode may be constructed by bending a substantially rectangular piece of the wire cloth to the shape of a cylinder of the required diameter and length, securing the meeting-edges together in any convenient manner, and attaching the supports to the cylinder by riveting or other suitable means. The woven wire cloth constituting the cylindrical anode *a* may be in a single piece bent to form a complete cylinder, or in two

Fig. 1.

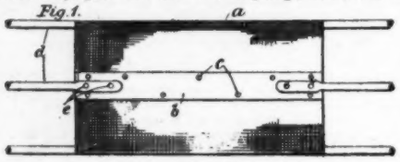
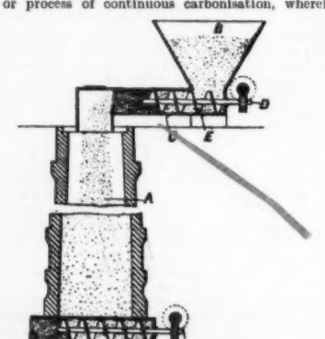


Fig. 2.

or more pieces, conjointly forming a complete cylinder, the meeting edges being butted together and held in position by means of an externally-applied strip *b*, which extends the entire length of the anode, and is secured to the adjacent margins by rivets *c*. In the example illustrated, wherein the anode is supported by three pairs of carrier bars *d*, the carrier bars *d*, *d* of each pair extending in alignment with one another beyond the opposite ends of the anode, the inner ends of the bars of a pair are riveted at *e* to the ends of the same strip *b*; there being thus three such strips, any one of which may be a jointing strip if the anode be formed of a single piece of wire cloth, or each of which may be a jointing strip, if the anode be made-up of three separate pieces. In any case, the strips *b*, carrier-bars *d*, and rivets *c* and *e*, are preferably of the same metal (say molybdenum) as that composing the woven wire cloth whereof the anode *a* is formed. (*Accepted May* 1, 1918.)

GAS ENGINES, PRODUCERS, HOLDERS, &c.

114,971. J. A. Yeadon and T. Whitaker, Leeds, Carbonising Coal. (1 *Fig.*) September 24, 1917.—The invention relates to carbonising coal, and consists in an improved method or process of continuous carbonisation, wherein the



coal, in the form of a very finely-ground powder, is mechanically caused to fall freely, continuously and directly through the entire length of an approximately uniformly-heated vertical retort or chamber, so as to be continuously completely and almost instantaneously carbonised during such fall, and in which the completely-carbonised coke produced is mechanically and continuously discharged from the bottom of said retort or chamber. Over the top of, and connected with, each retort A, a hopper B, combined with a horizontal cylinder C, is fixed. The cylinder is open at the top under the hopper to receive the prepared fine coal. In this cylinder C is a revolving shaft D, having screw E, by which the fine coal is carried continuously to the mouthpiece of the retort. As the fine coal is continuously discharged from the end of the cylinder C into the top of the retort A, it becomes broken up, and in falling freely and directly through the entire length of the heated retort, it becomes almost instantaneously carbonised, thus releasing the gases continuously at their richest quality, and allowing the carbon or coke to fall continuously to the bottom of the retort A. The bottom of the retort A is fitted with a continuous discharging apparatus for the coke on a similar principle to the apparatus feeding in the coal at the top, namely, an open-top cylinder G under the retort, fitted with a revolving shaft H and screw I. (*Accepted May* 1, 1918.)

114,947. W. Comery, Mapperley Park, Nottingham, and The Raleigh Cycle Company, Limited, Lenton, Nottingham. Internal-Combustion Engines. (4 *Figs.*) July 24, 1917.—This invention relates to internal-combustion engines of the type in which the induction pipe is heated by contact with the engine structure. The cylinders *a* and *b* are, as usual, arranged one on either side of the crank case *c*. The latter is formed with an extension *d*, to the top of which is bolted the magneto *e*, the timing gear case *f* lying on the side face of the crank-case *c* and extension *d*. A cover *g* is provided for the timing gear case *f*, and upon the cover *g* is fixed the carburettor

Fig. 1.

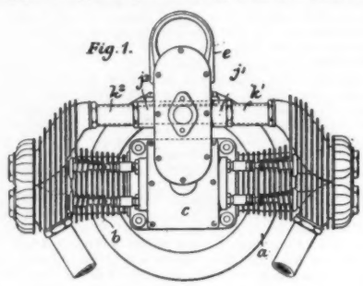
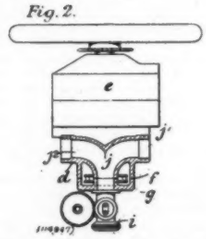


Fig. 2.



communicating with a conduit *j*, passing through the timing gear case *f*. The conduit continues into the extension *d*, where it branches to right and left, forming two outlets *j*1 and *j*2, which communicate, by means of short lengths of piping k1, k2, with the inlet valve chambers of the cylinders *a* and *b* respectively. By these means, the inlet passages from the carburettor are maintained hot by conduction of heat from the crank case through the timing-gear case, thereby pre-heating the petrol vapour or preventing the same becoming condensed, whilst the exposed portions of the fuel inlet piping are reduced to a minimum. (*Accepted May* 1, 1918.)

MACHINE AND OTHER TOOLS, SHAFTING, &c.

114,900. S. Hughes, C. F. Boggon, and D. Lumsden, Shotts, Lanarkshire, and the Firm of Paton and Dick, Glasgow. Drilling Machines. (3 *Figs.*) April 24, 1917.—This invention relates to an improved mount for boring machines,

Fig. 1.

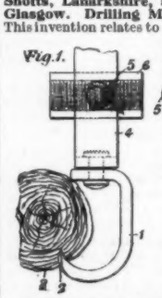


Fig. 2.

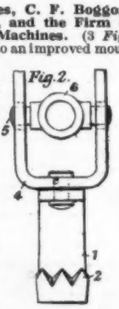
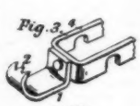


Fig. 3.



for use in boring coal and other minerals. A construction according to the invention, comprises a clamping element of substantially C form, having teeth to bite into a prop, and a U-shaped carrier having a swivel connection with said clamping element, the limbs of said U-shaped carrier being slotted for a purpose hereinafter described. A device according to the invention comprises a rigid grip or clamping element 1 of substantially C-form at one end with teeth or spikes 2 adapted to be driven into a prop 3, used for supporting the roof of a working. Swivelled to said grip 2 is a carrier 4 of substantially U-shape, the limbs of which are slotted for engagement by projecting pins 5 on the nut-forming member 6 in which works the usual screw for the drill feed. As will be evident, the grip 1 can be readily and rapidly disengaged from the prop 3 on the completion of the boring operation, without disturbance of the prop 3, which remains in position during the firing of the shot. (*Accepted May* 1, 1918.)

MINING, METALLURGY AND METAL-WORKING.

114,885. D. F. Campbell, London. Heating Metallic Bodies. (3 *Figs.*) April 17, 1917.—The invention relates to heating metallic bodies in series by the passage of a current of electricity derived from a source of low voltage and large amperage. The bodies to be heated are arranged to form part of a circuit traversed by a current of electricity of low voltage and of sufficient amperage to raise the temperature to the required extent, the heat developed being due to the electric resistance of the metallic bodies. A1, A2, A3 . . . are blanks to be heated in contact with conductors B1, B2, B3 . . . which may be of carbon, iron, copper or other suitable material; the conductors B1, B2, B3

Fig. 1.

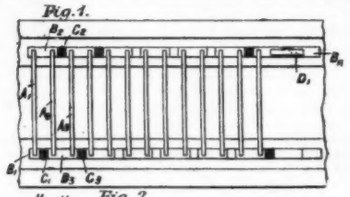
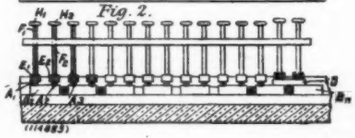


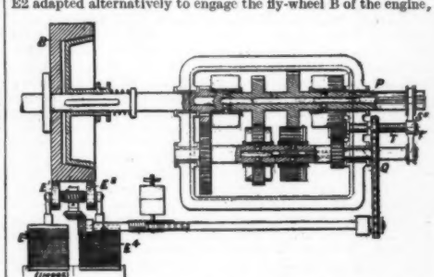
Fig. 2.



are separated by blocks C1, C2, C3 . . . of suitable insulating material. Short-circuiting bars such as D1 bridge the insulating blocks where any of the blanks are omitted. If the current enters at the left of the series at the conducting block B1, it traverses the bar A1, conducting block B2, bar A2, conducting block B3, and so on to the right-hand conducting block Bn. The bars A1, A2 . . . are pressed into good conducting contact with th conductors B1, B2 . . . by blocks E1, E2 . . . of insulating material carried at the lower ends of bars F1, F2 . . . screw-threaded into rails G disposed vertically above the conductors B1, B2 . . . The contact pressure can be adjusted by the hand wheels H1, H2 . . . (*Accepted May* 1, 1918.)

MOTOR ROAD VEHICLES.

114,995. E. Fehr, Wembley Hill, and R. Reimann Erdington, Birmingham. Change-Speed Mechanism. (4 *Figs.*) November 28, 1917.—The invention comprises improvements in change-speed mechanism of the type in which a hollow-driven shaft and a hollow lay shaft parallel thereto have two coupled axially-adjustable spindles located one in each of the shafts, and abutments on the spindles are adapted to engage operatively with loose gear-wheels on the shafts for the purpose of engaging or disengaging said gear-wheels to or from the shafts. According to this invention, the change-speed mechanism is provided with a rotatable screw-threaded rod T, longitudinally immovable, a nut S2 thereon, rigidly connected to the two axially-adjustable spindles P, Q, and two friction wheels E1, E2 adapted alternatively to engage the fly-wheel B of the engine,



and operatively connected with the rod T to rotate the latter in opposite directions. Thus, when one or the other of the friction wheels is caused to engage the fly-wheel, the rod is caused to rotate in one or other direction, and the nut travels along the rod, thereby moving the spindles axially, so that abutments thereon are brought into operative engagement with the gear-wheels as desired. The friction wheels can be electrically controlled by two electro-magnets E3, E4, alternatively energised to move one or the other of the friction wheels into engagement with the fly-wheel, a hunting switch being connected in series with the electro-magnets and rotated by the friction-wheel drive until the hunting switch opens the circuit, de-energises the operating electro-magnet, and thus disengages the friction wheel from the fly-wheel. (*Accepted May* 1, 1918.)

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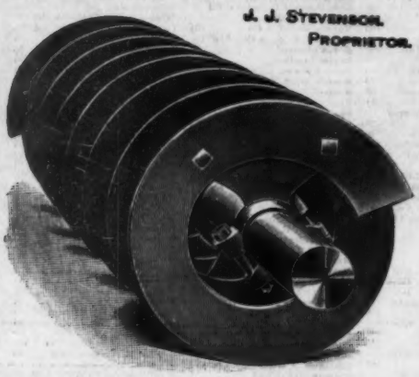

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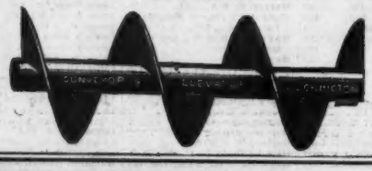

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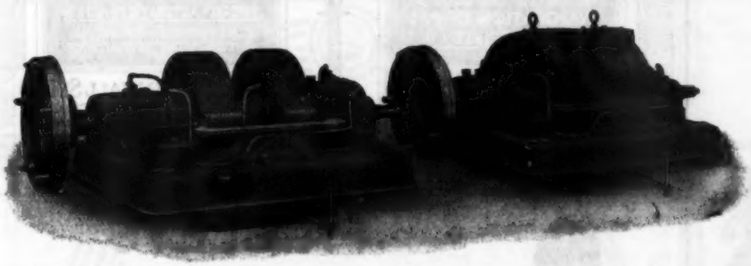

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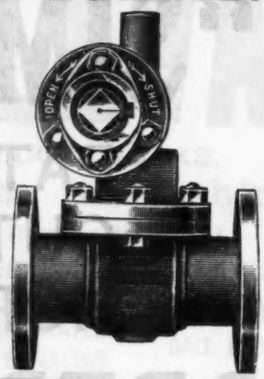

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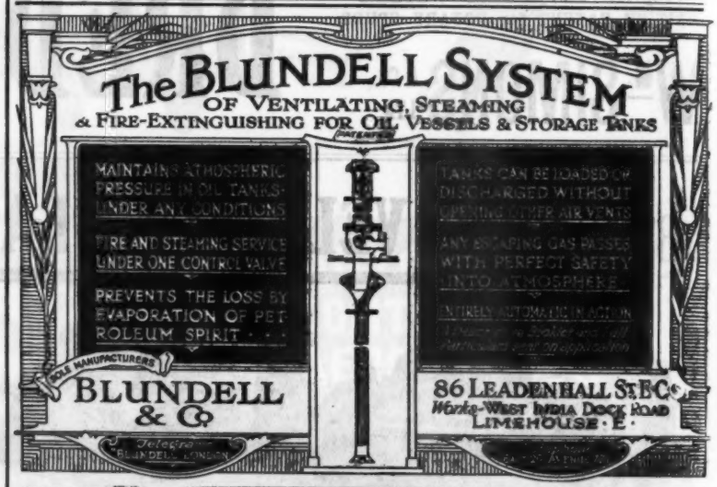
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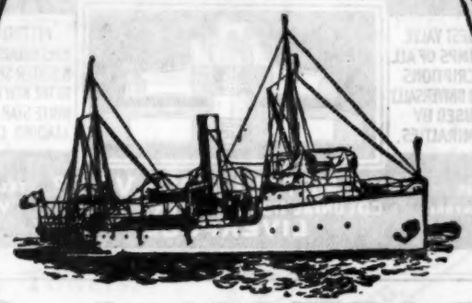

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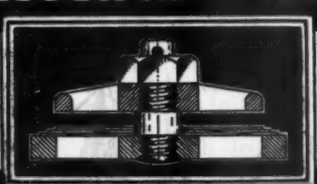

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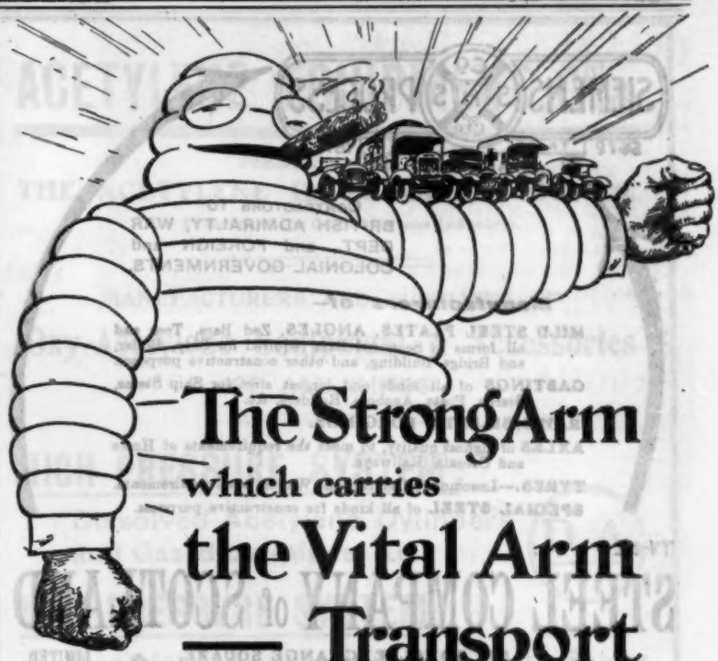

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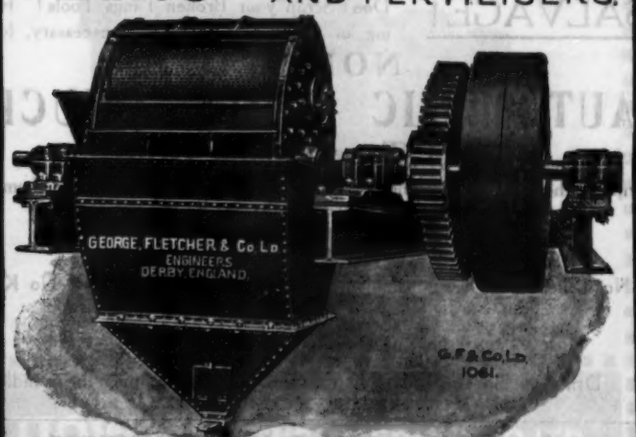

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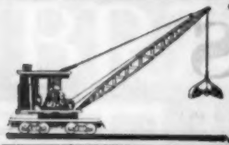

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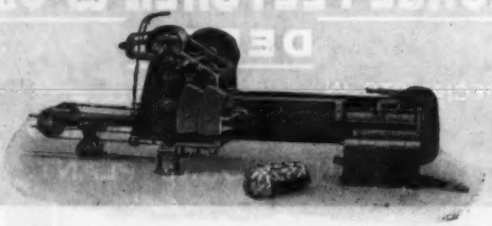

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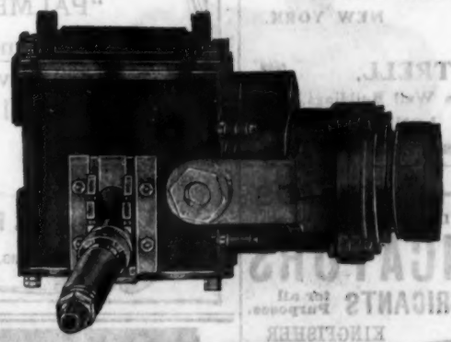

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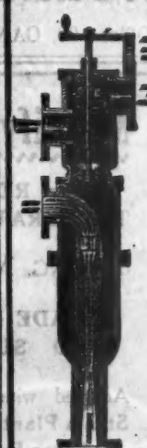

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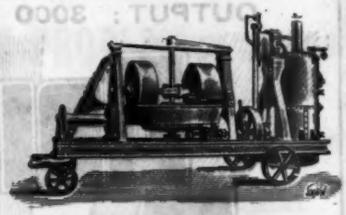

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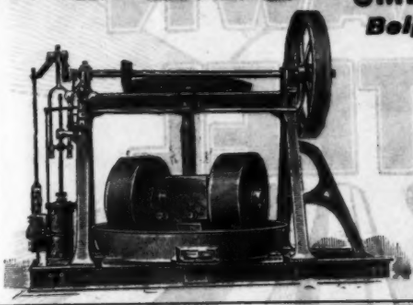

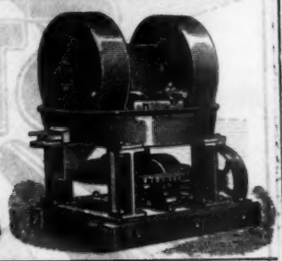

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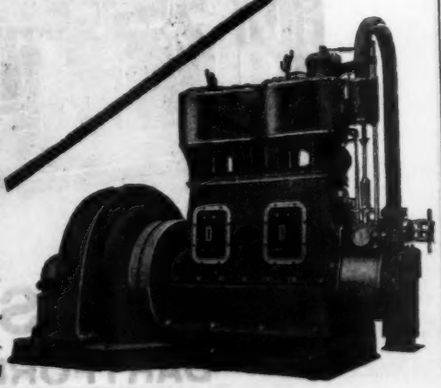

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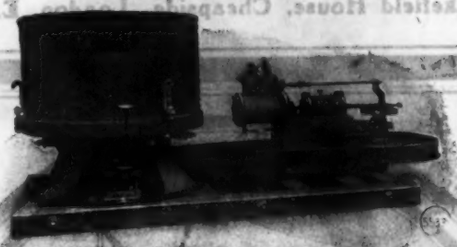

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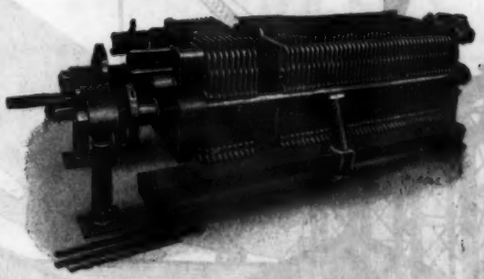

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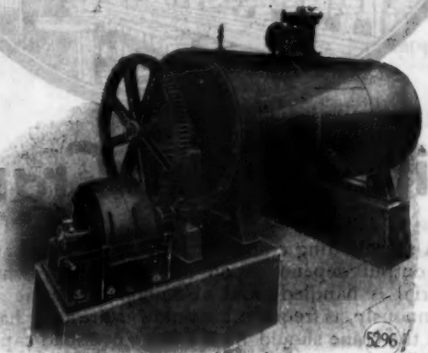

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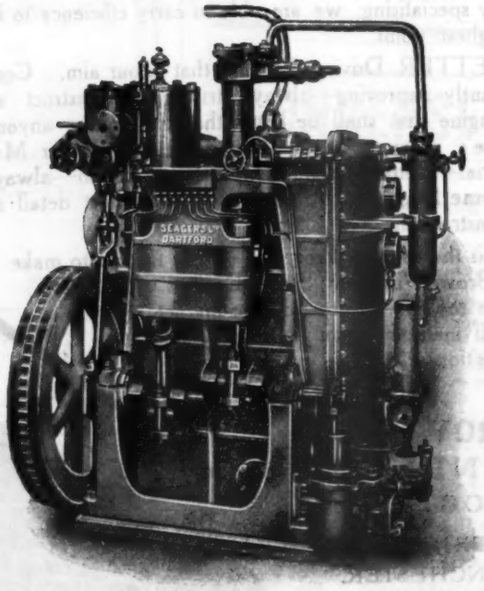

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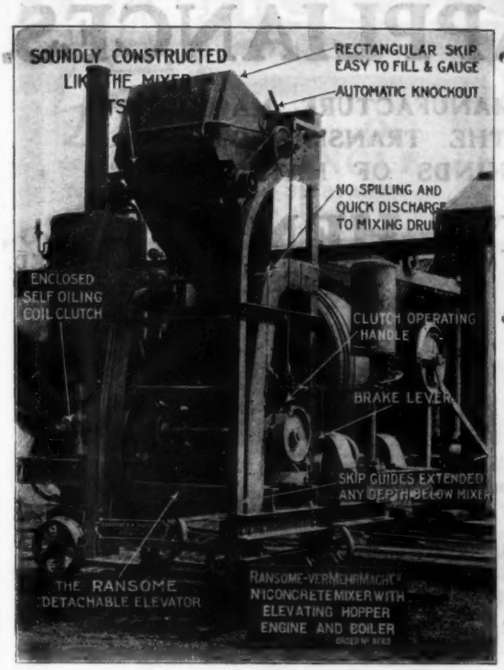
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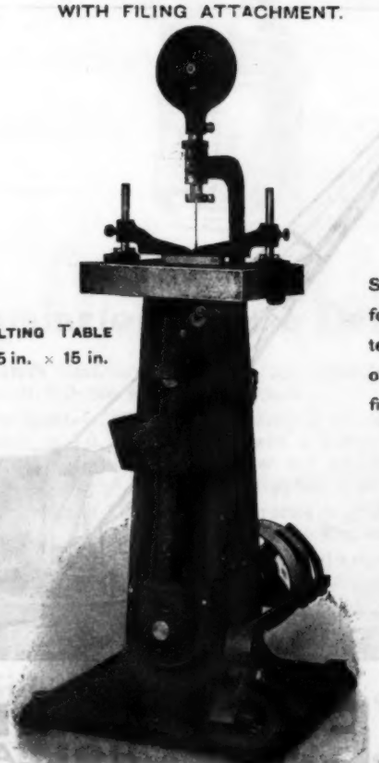

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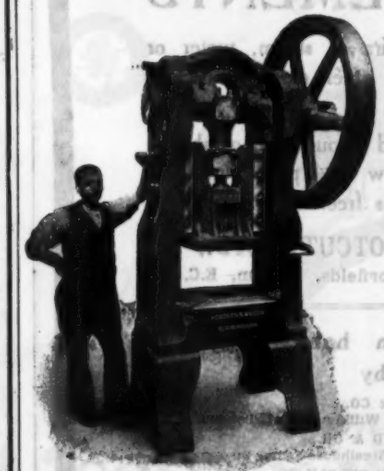

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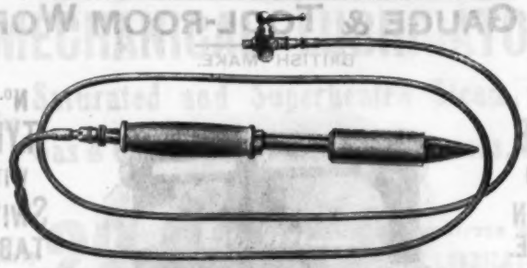

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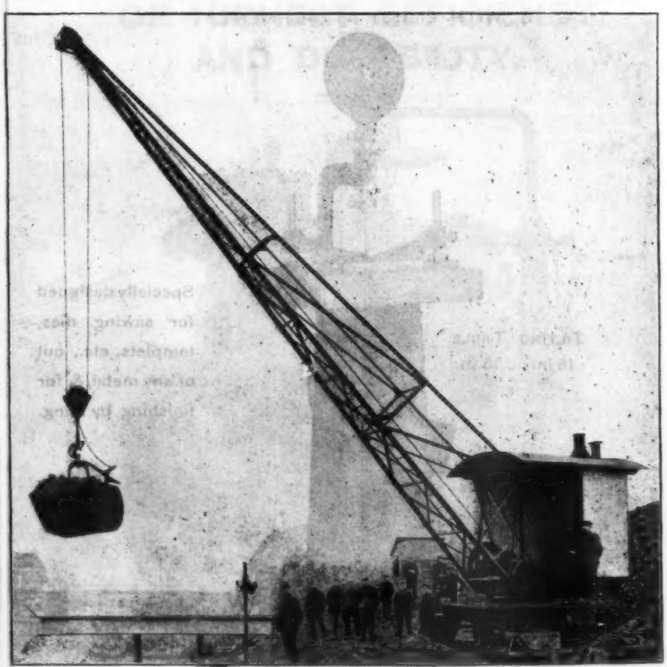

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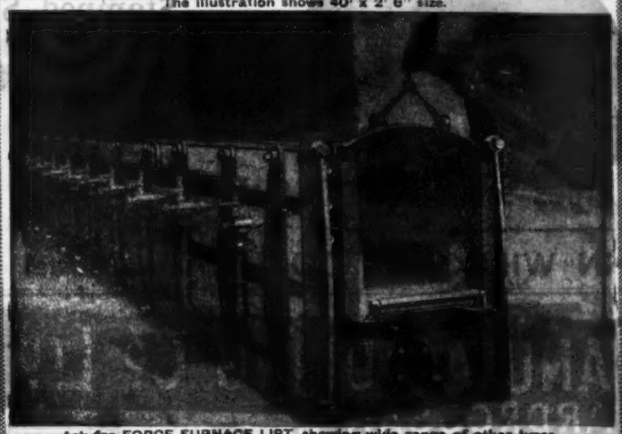

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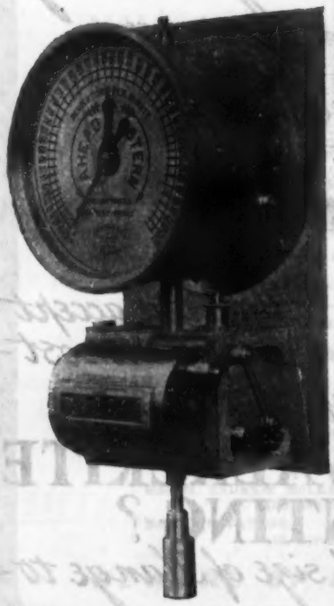

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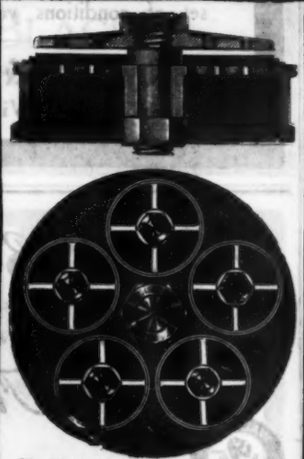

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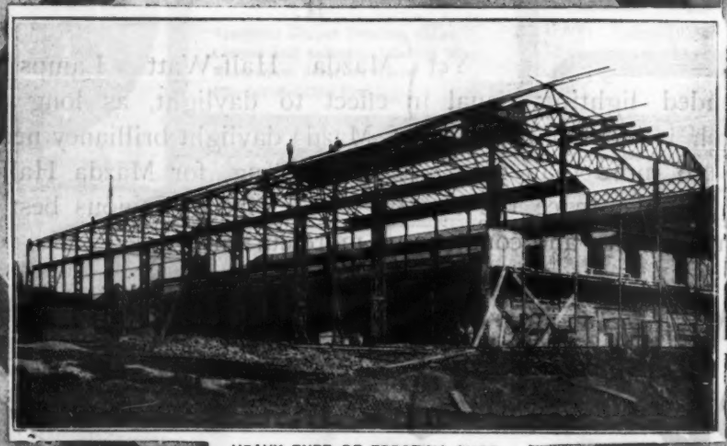

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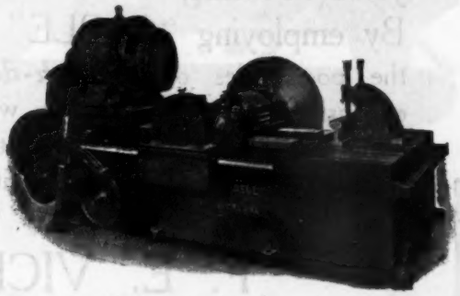

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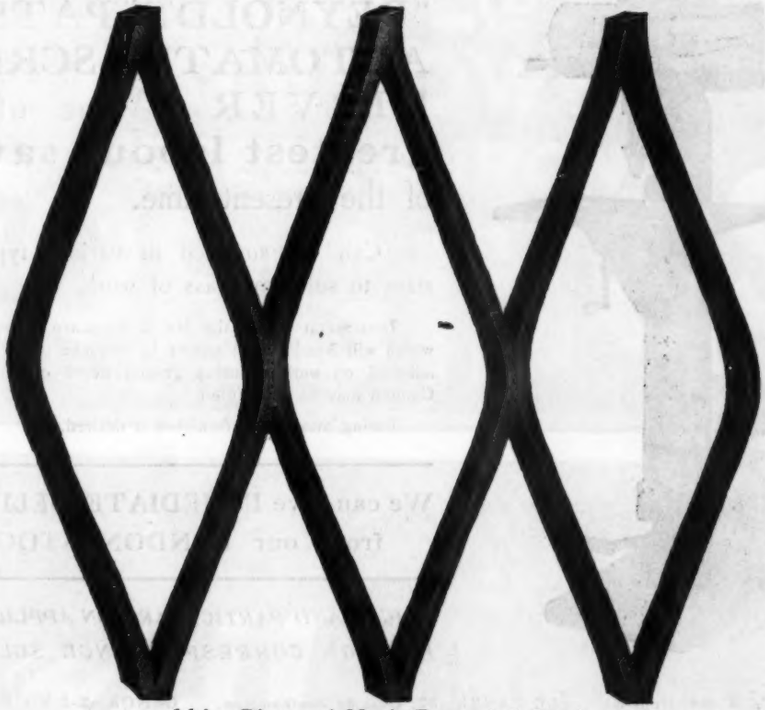

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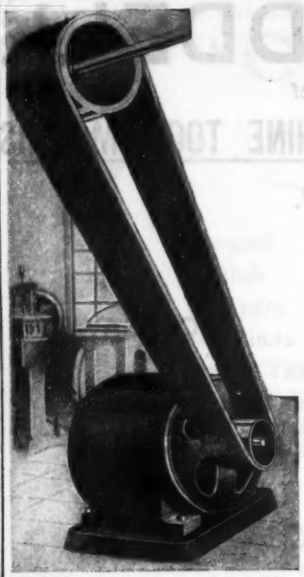

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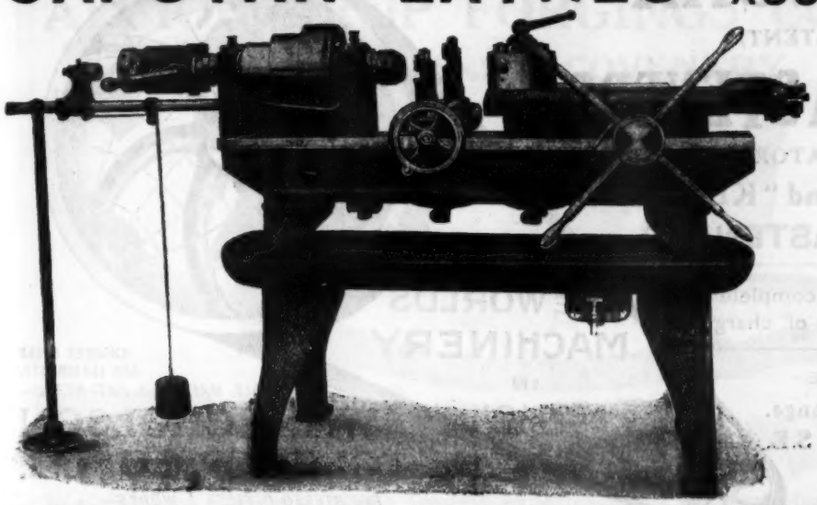

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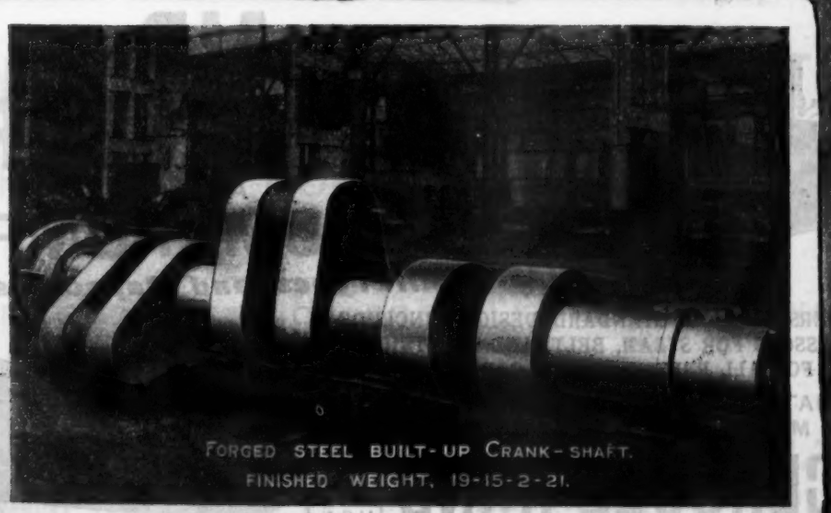

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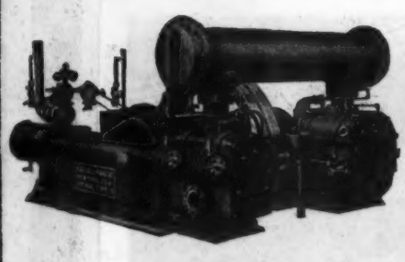

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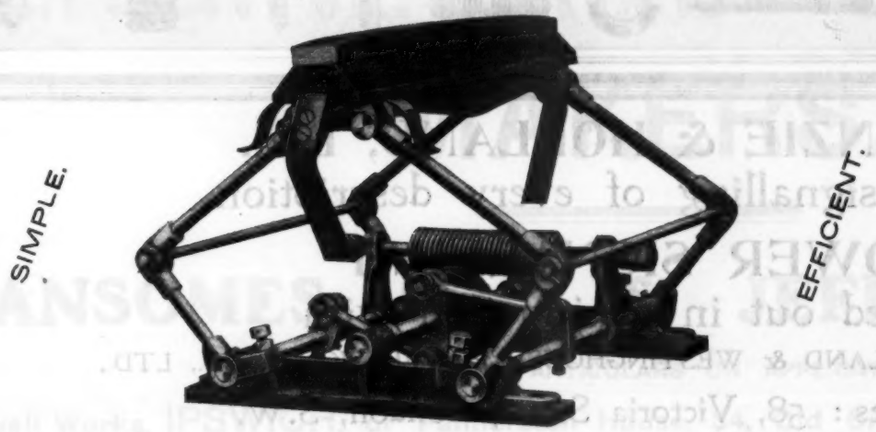

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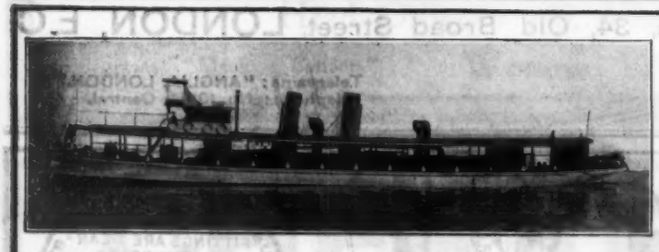

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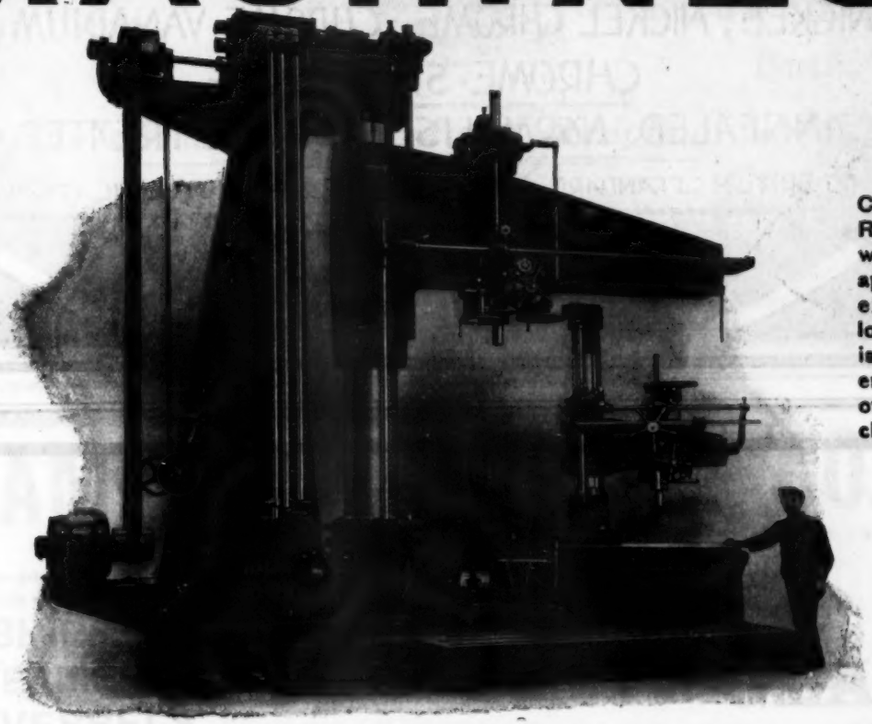

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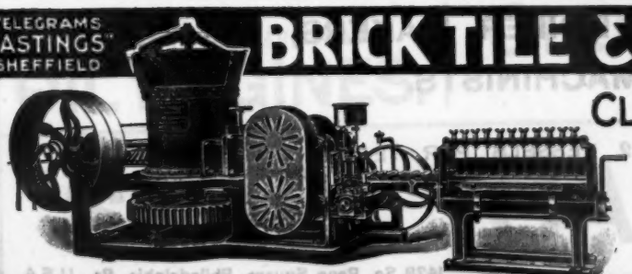

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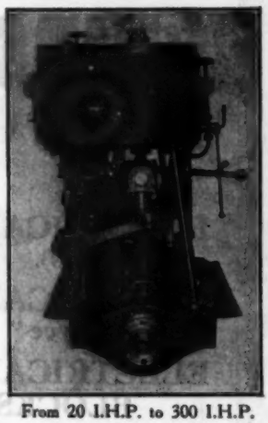

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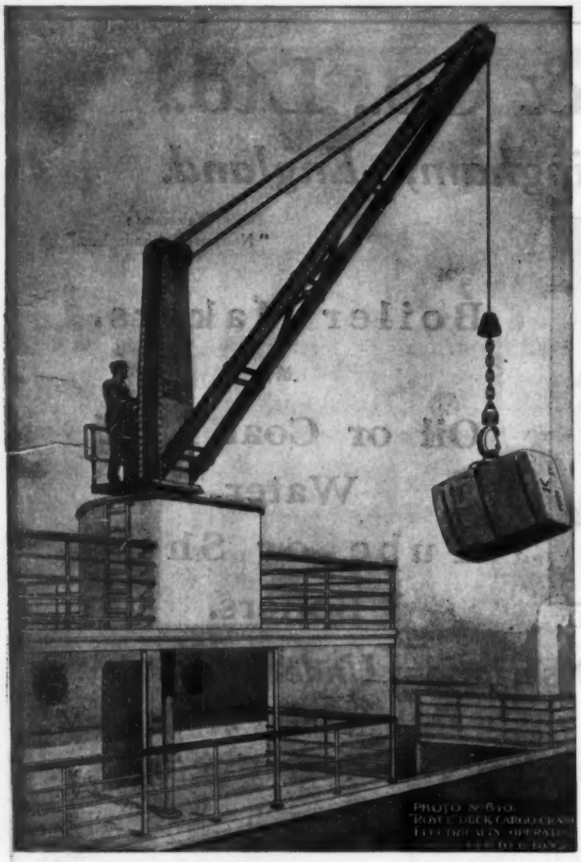

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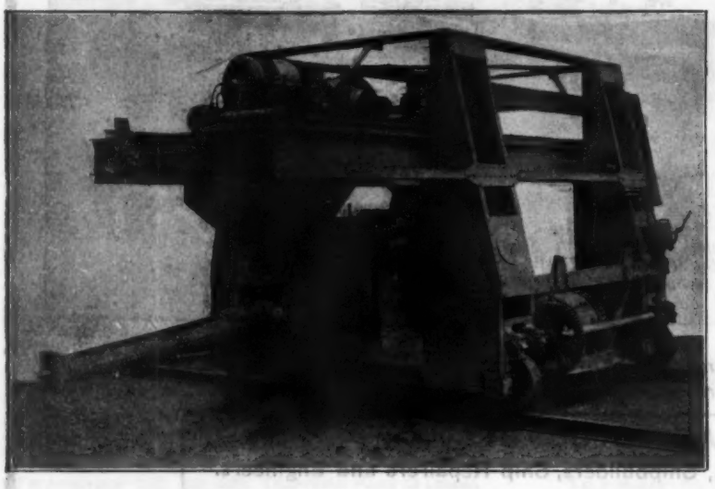

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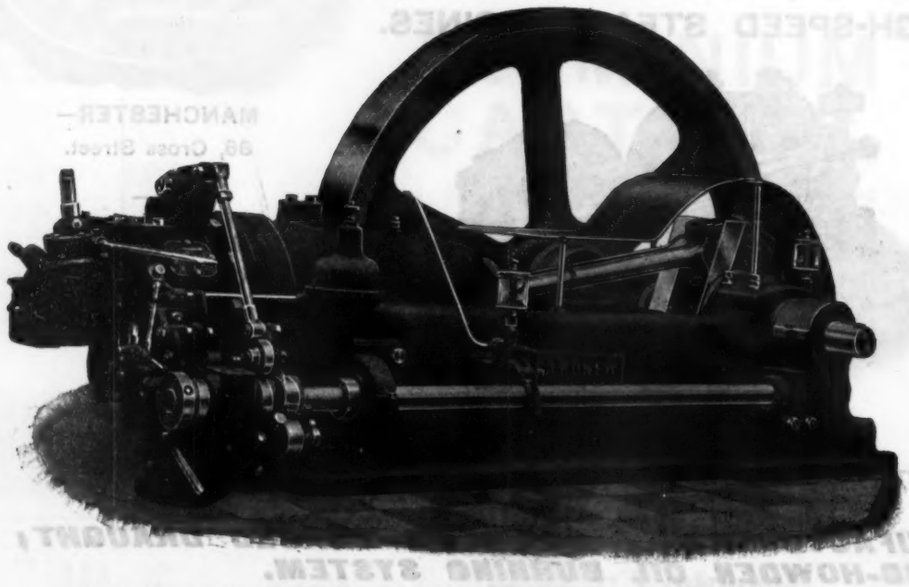

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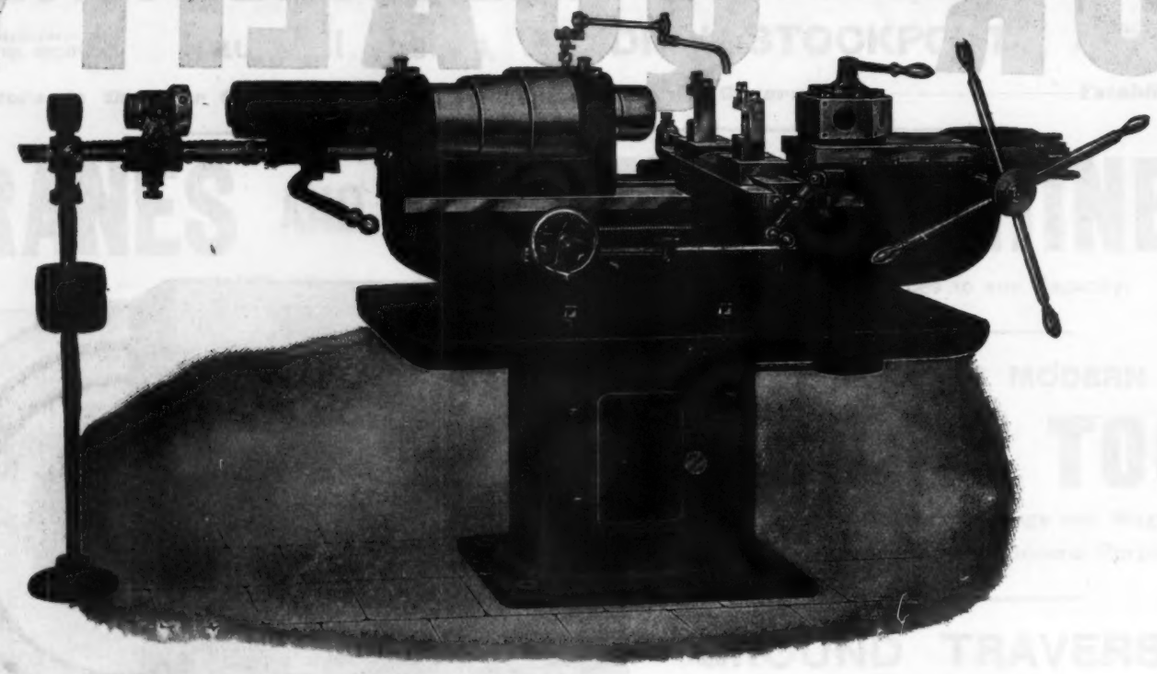

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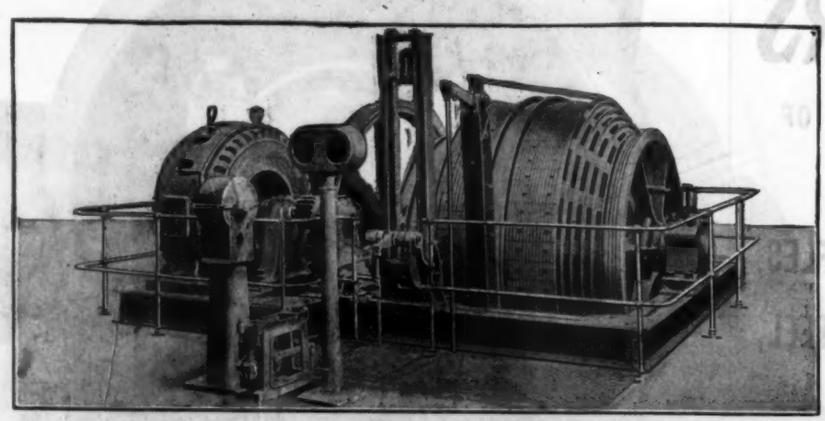

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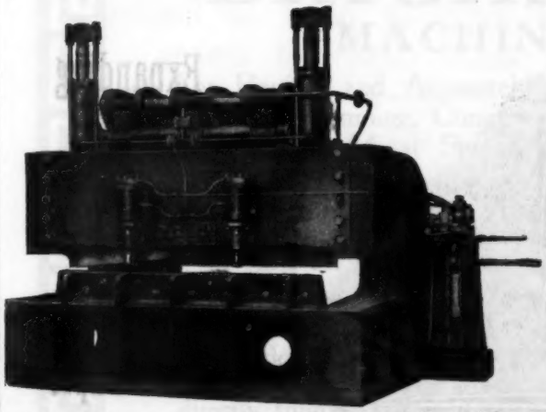

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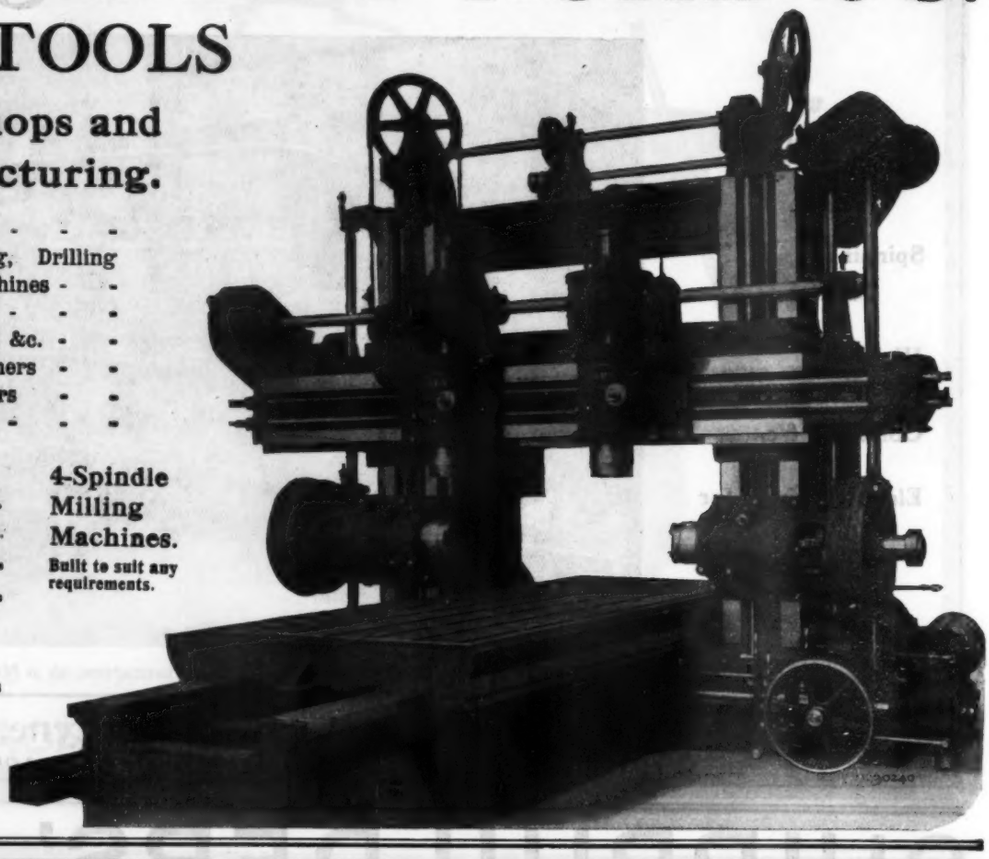

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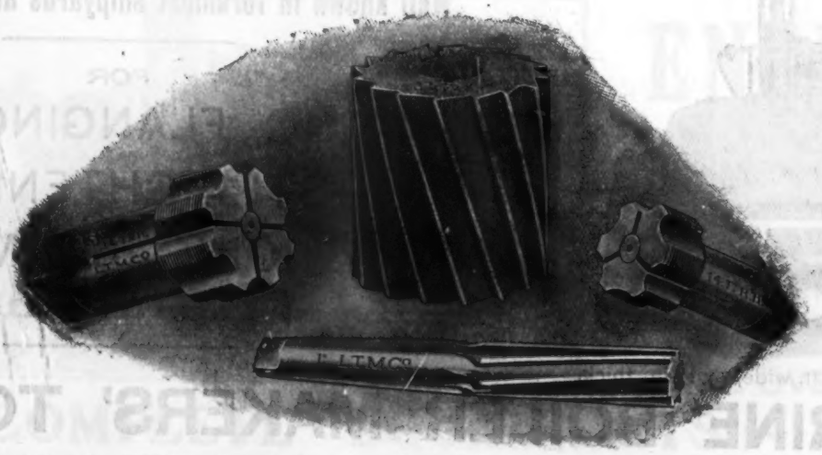

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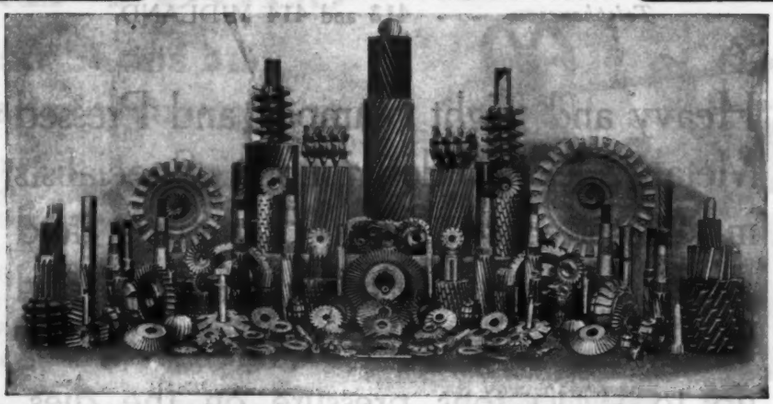

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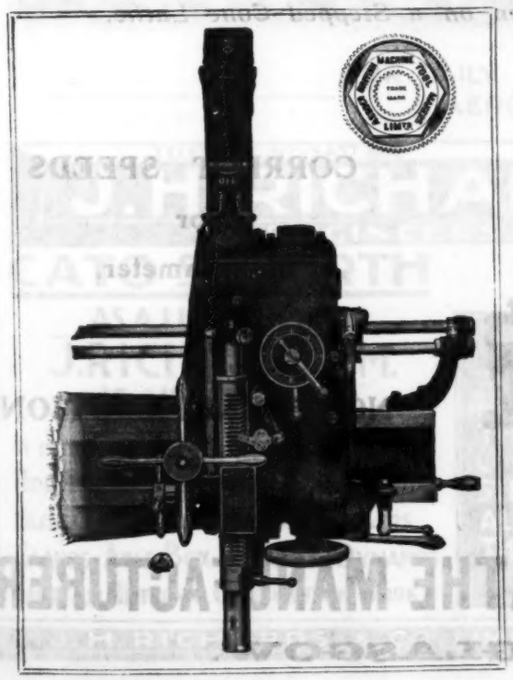

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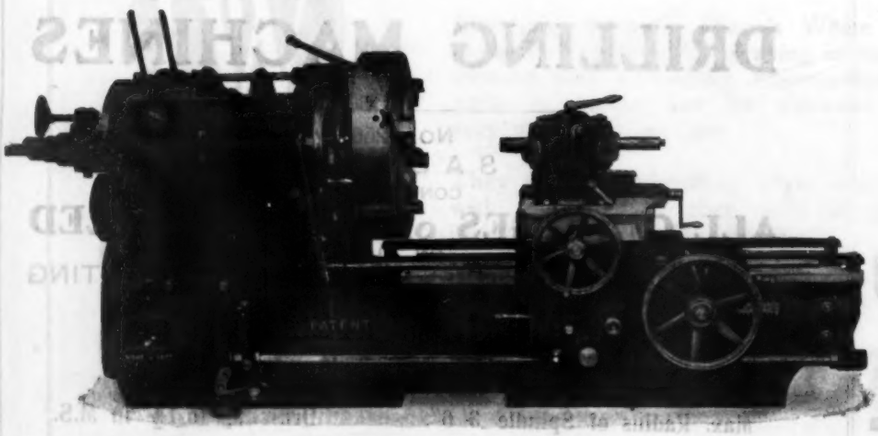

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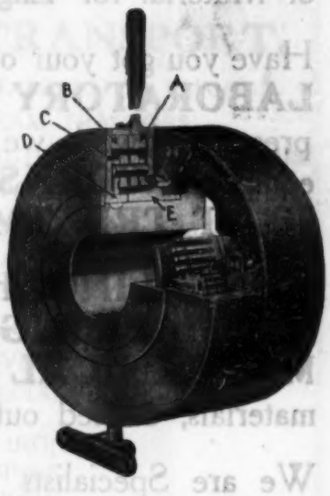

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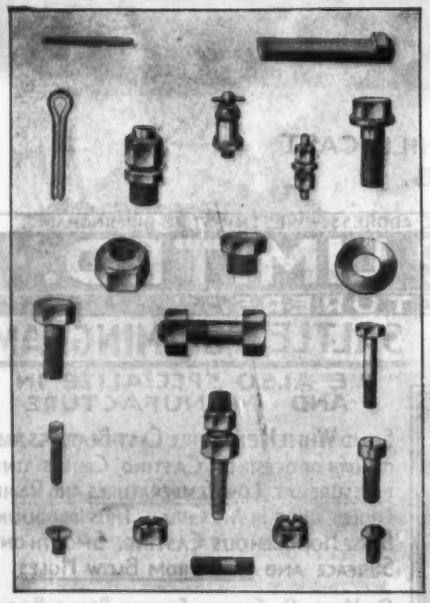

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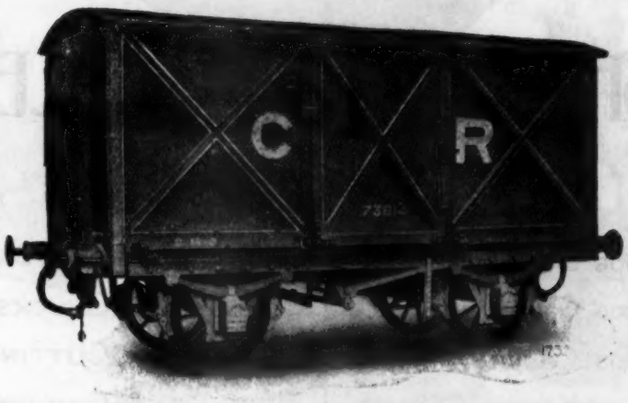

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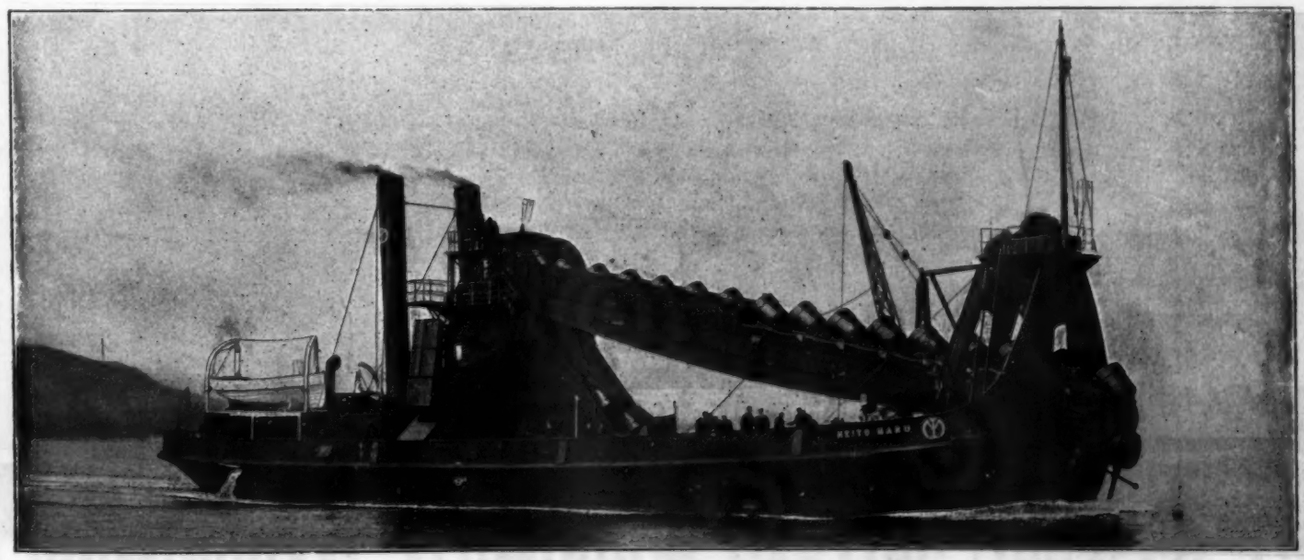

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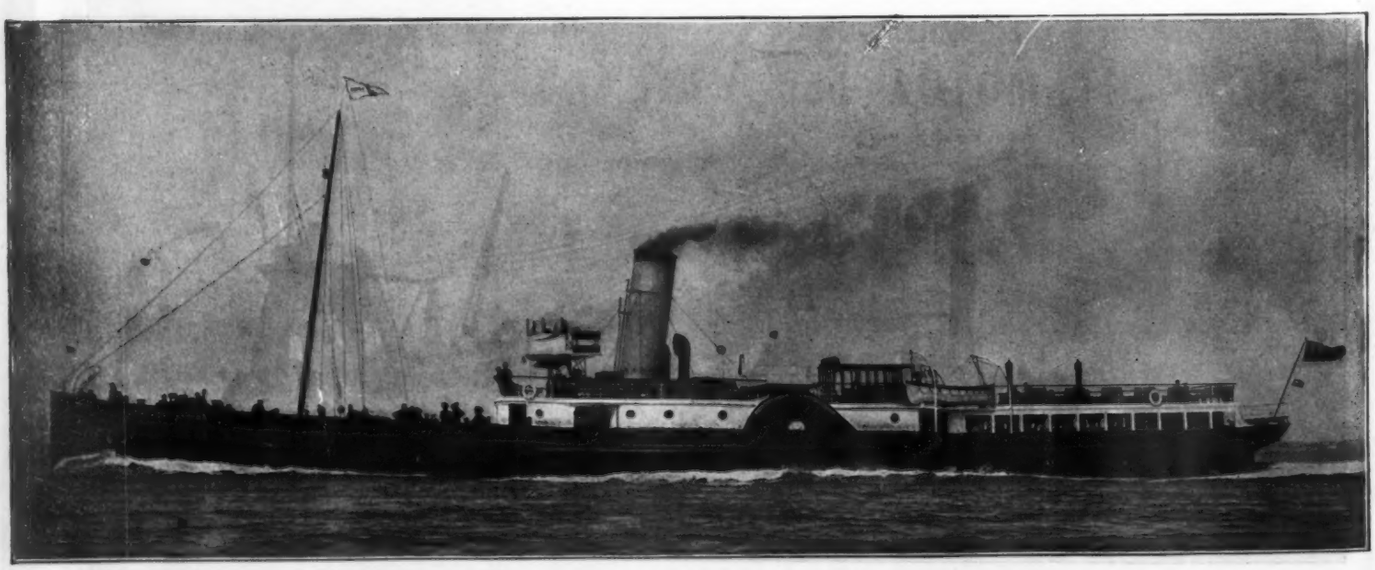

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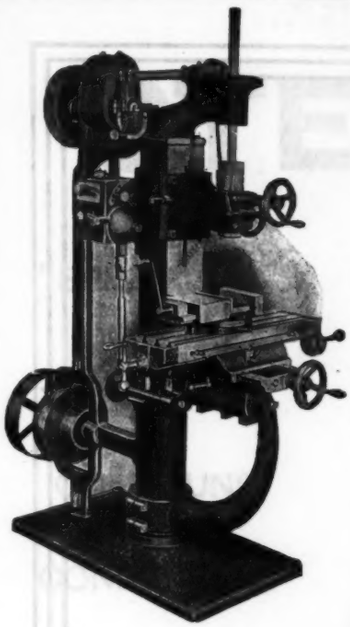

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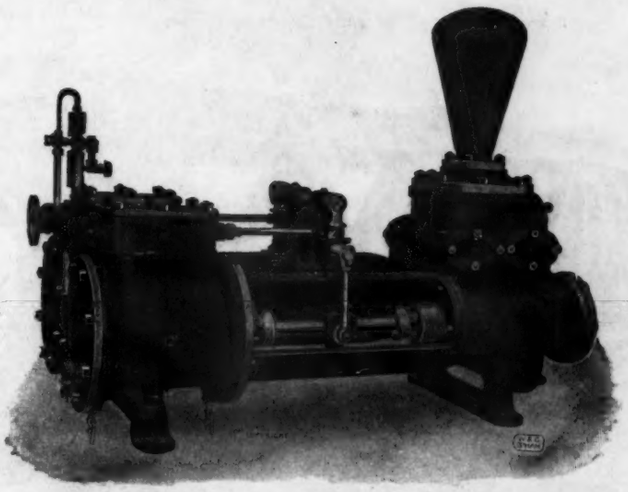

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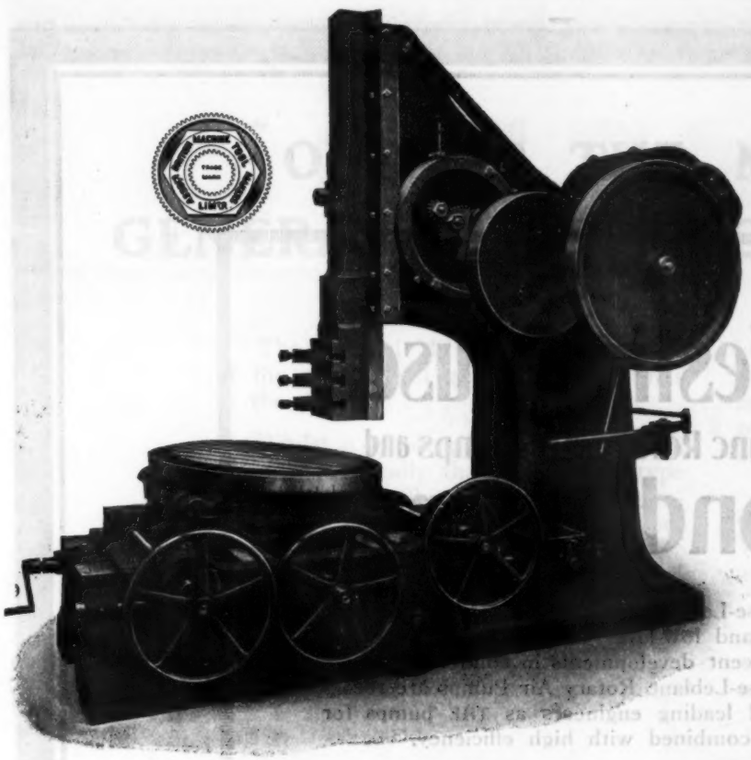

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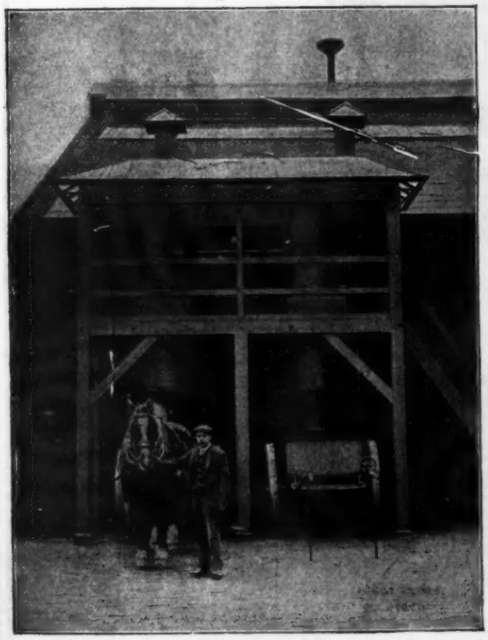

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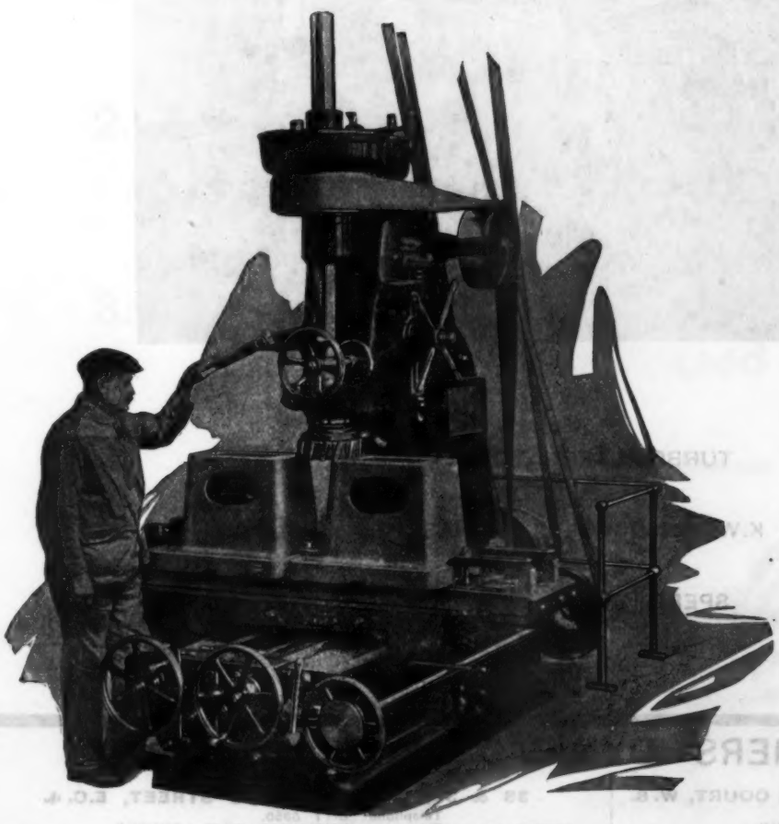

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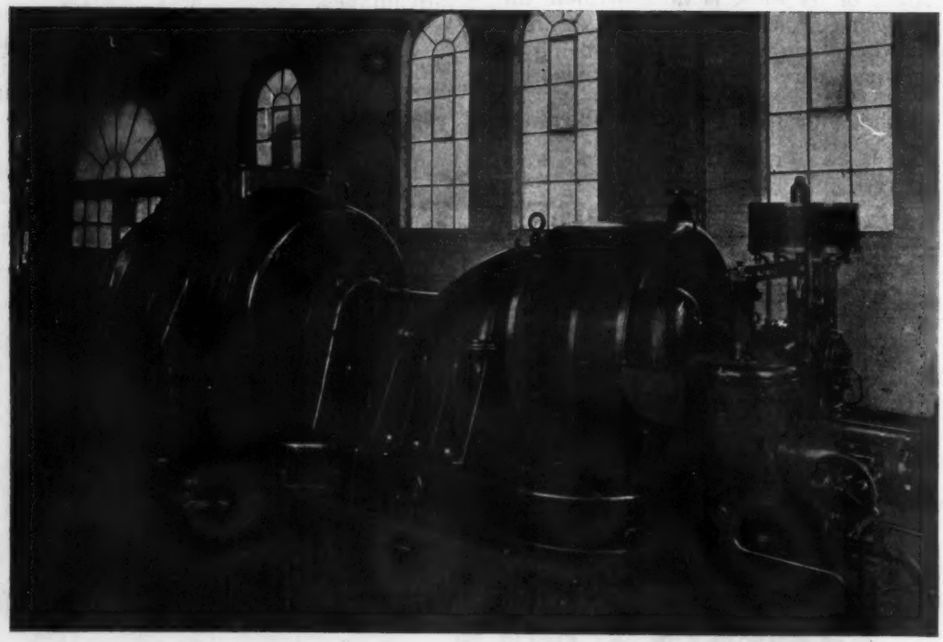

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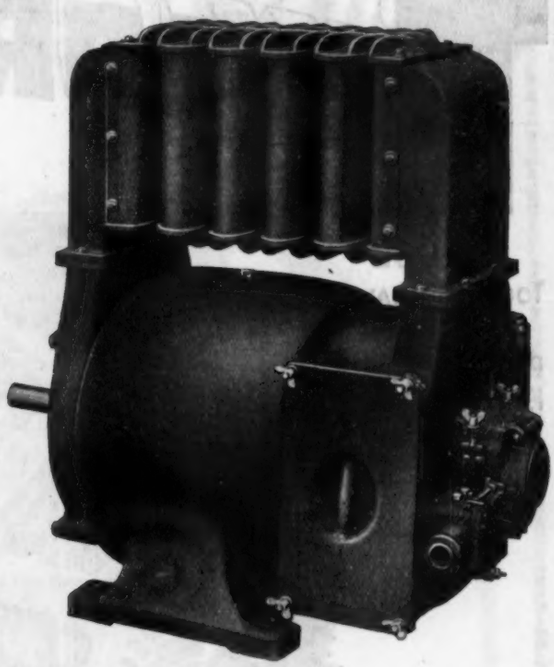

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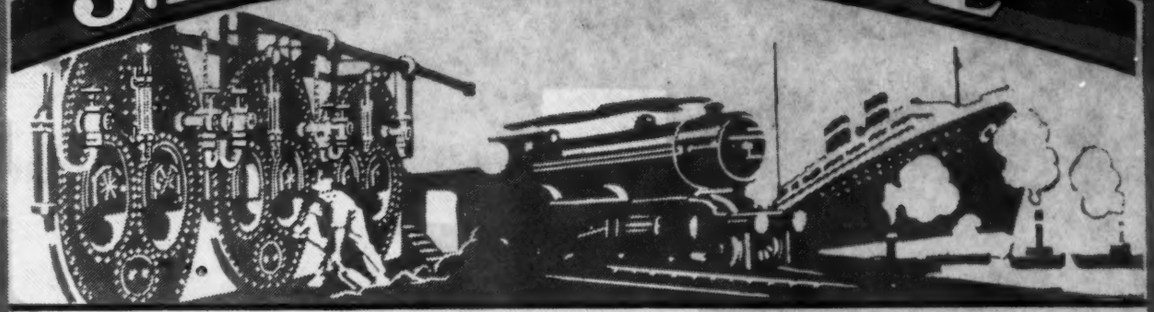

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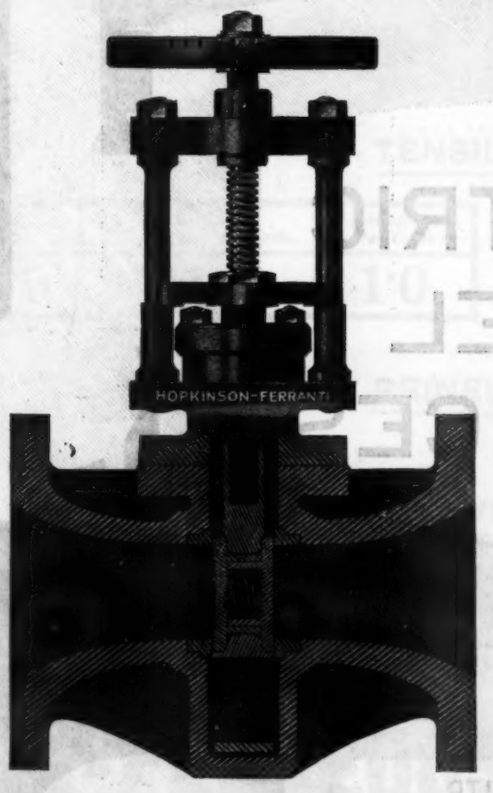

FIGURE 2028 (CAST IRON).
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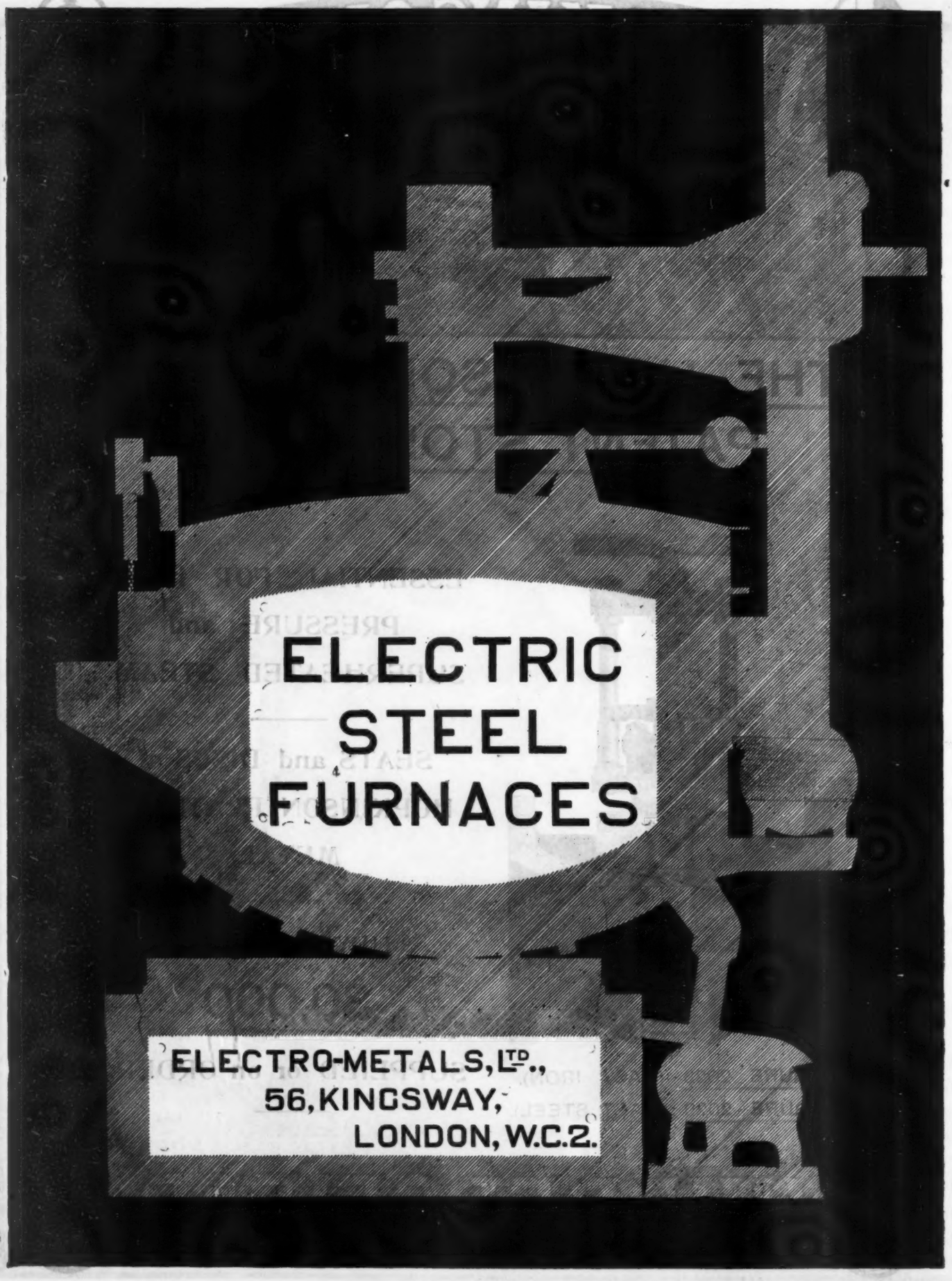
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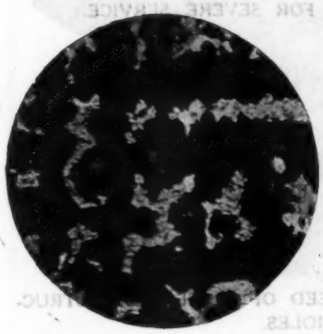

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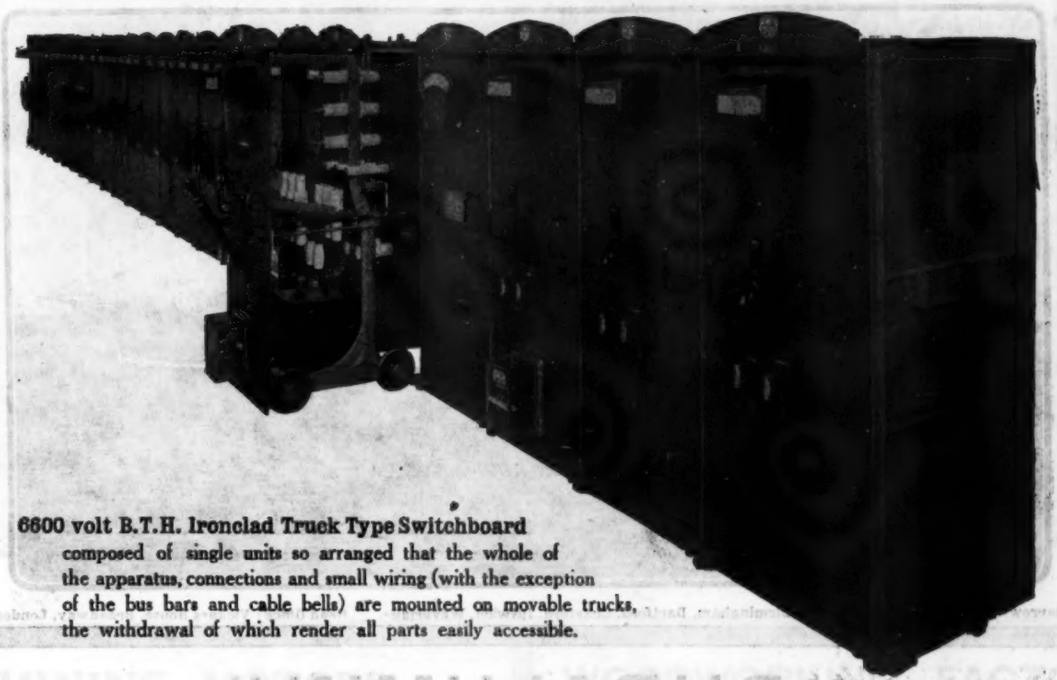

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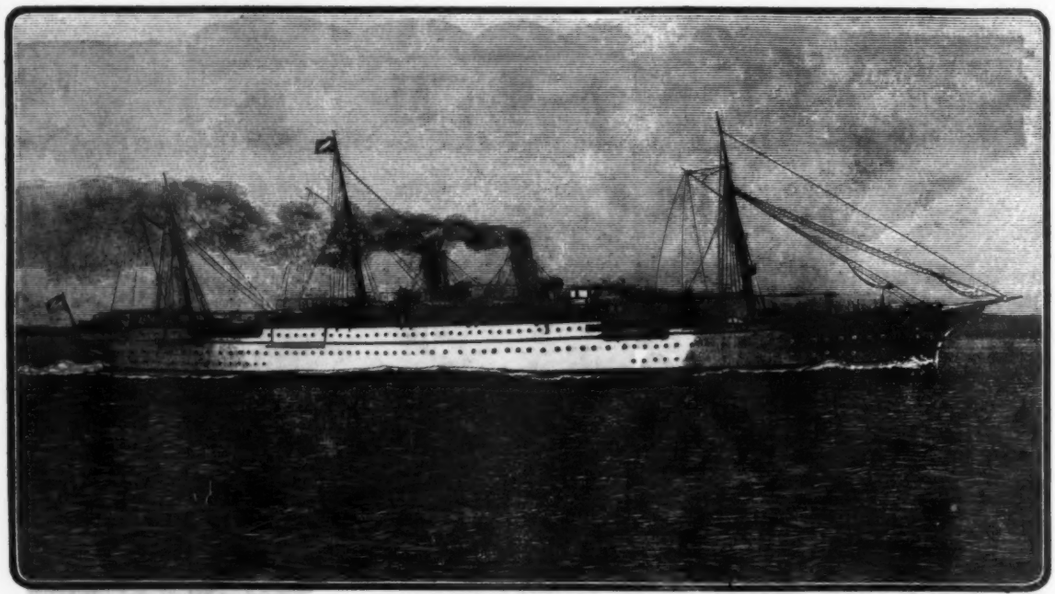

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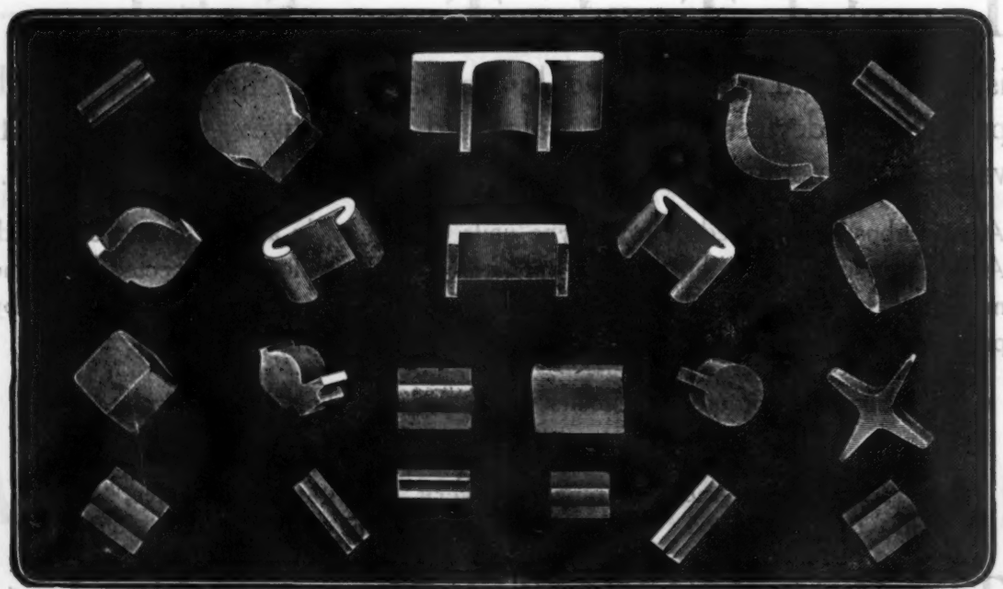

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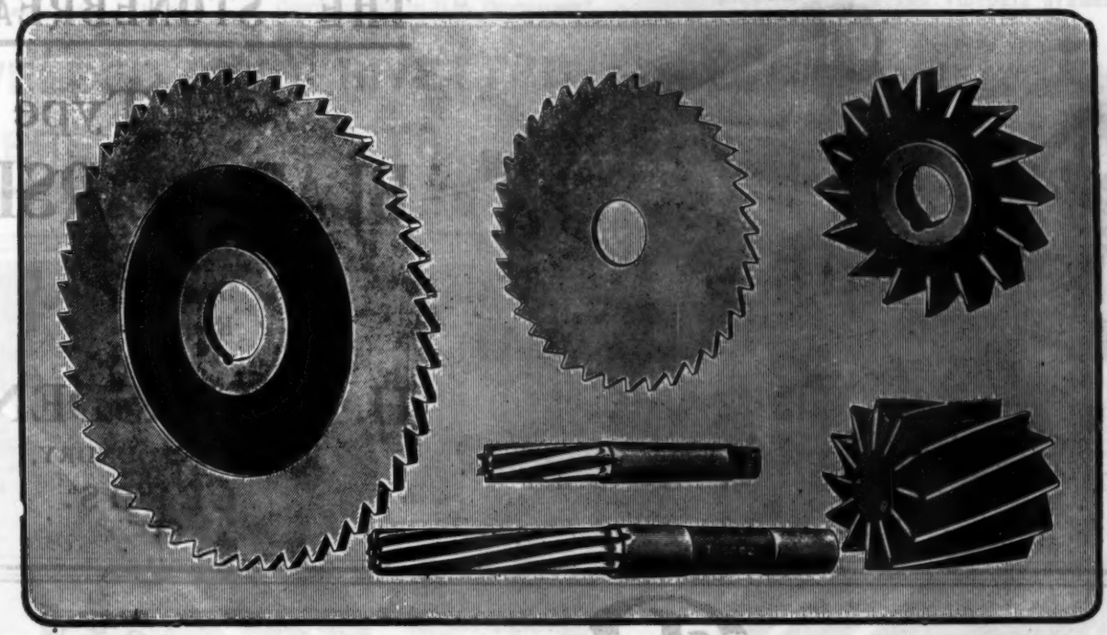

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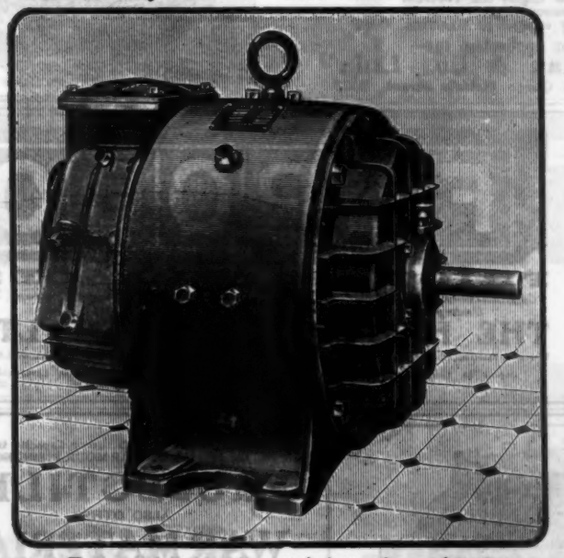

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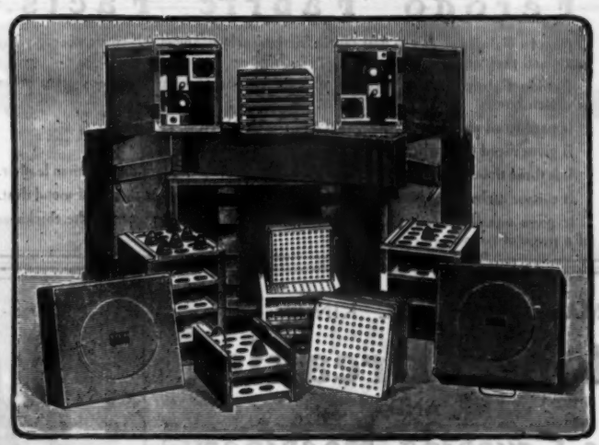

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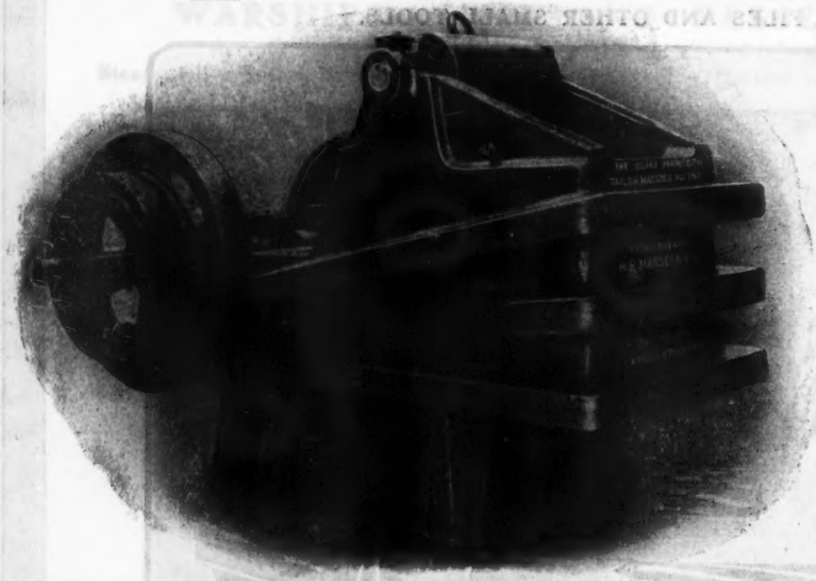

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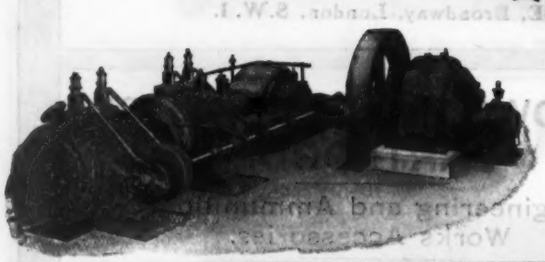

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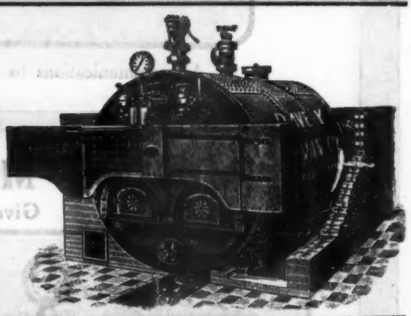

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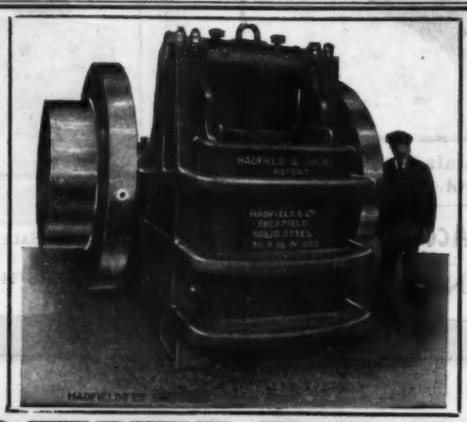

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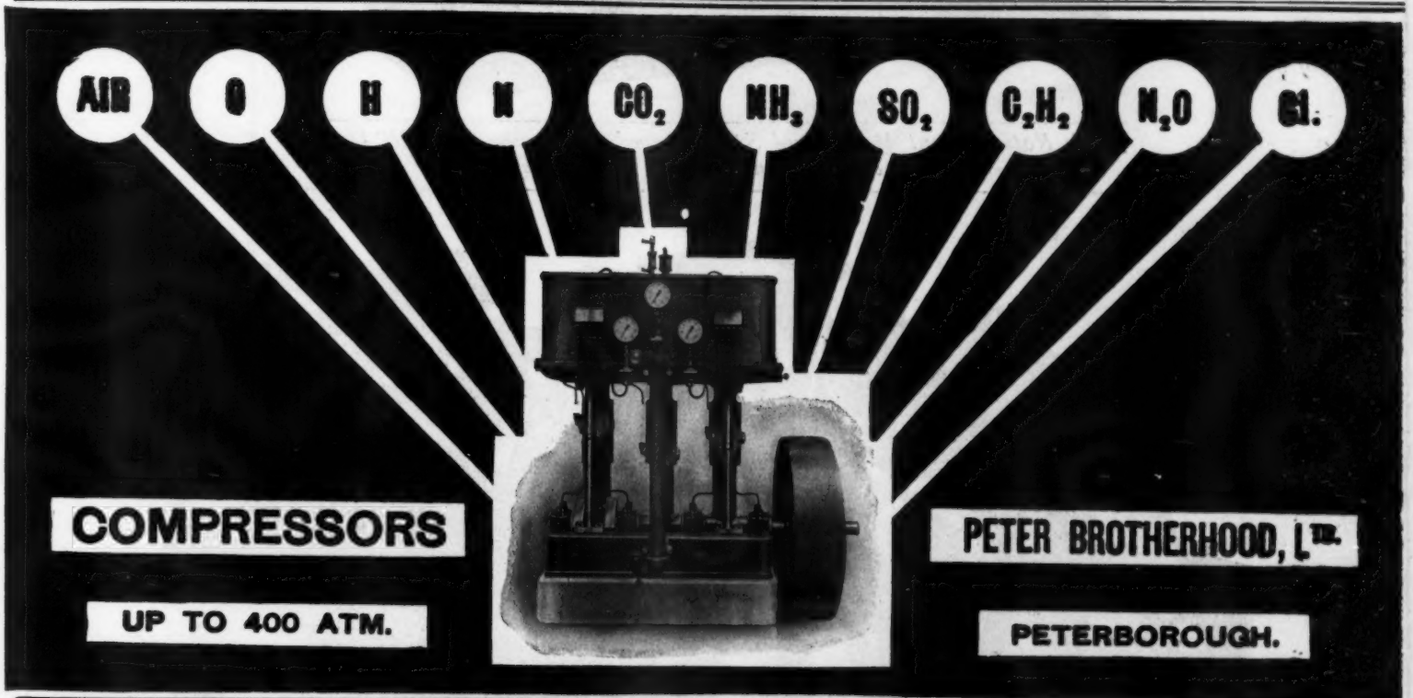

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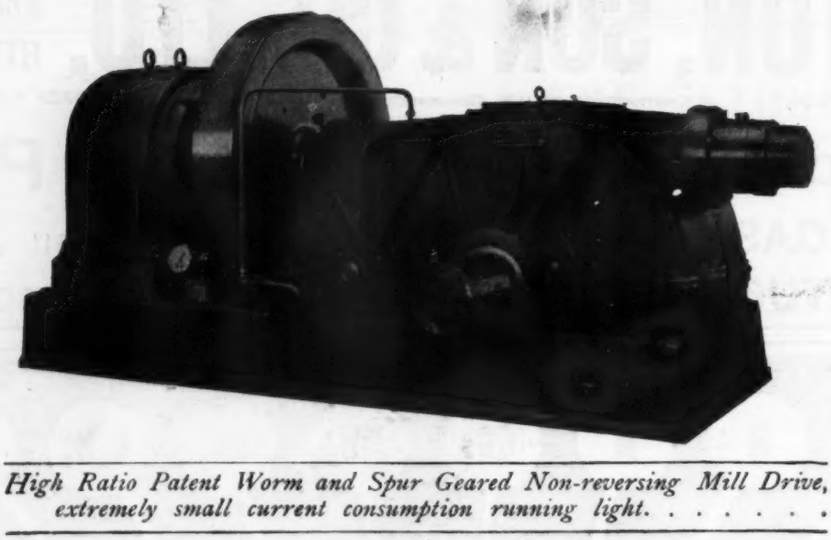

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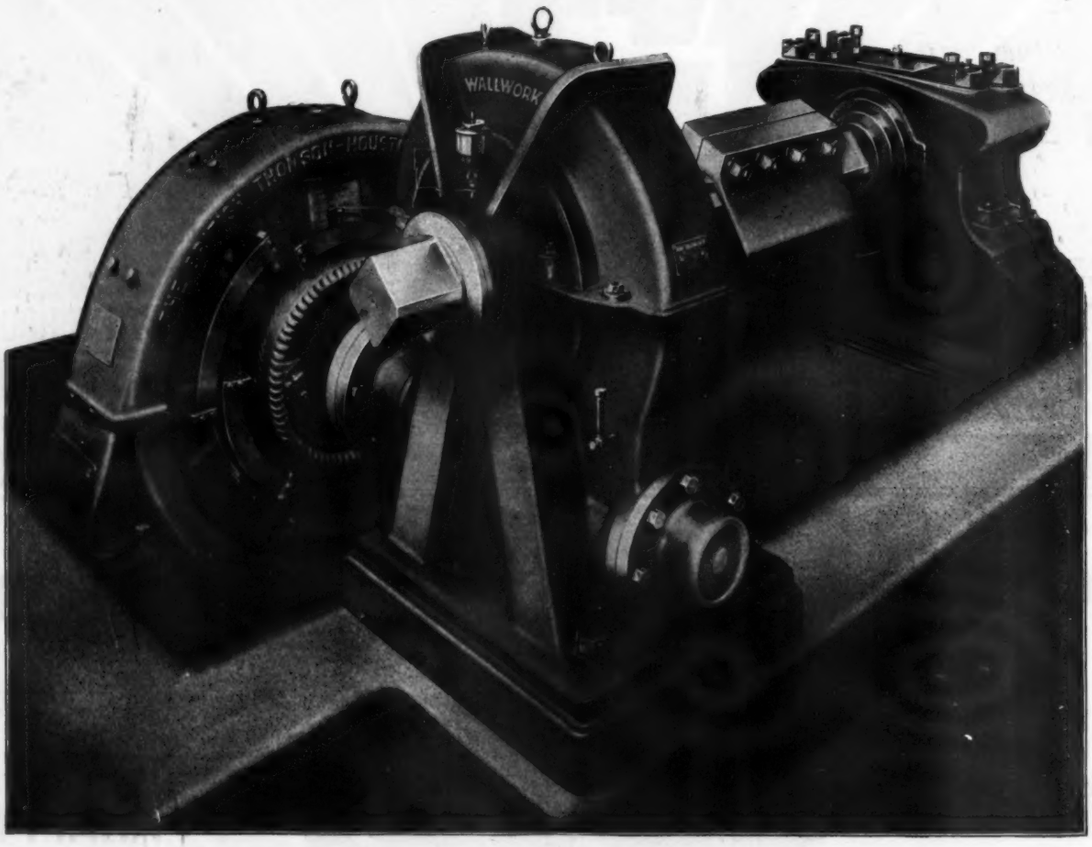

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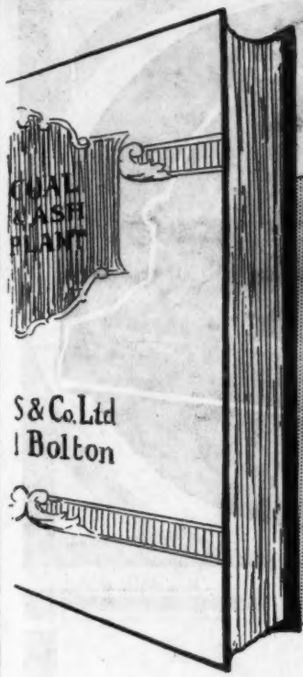

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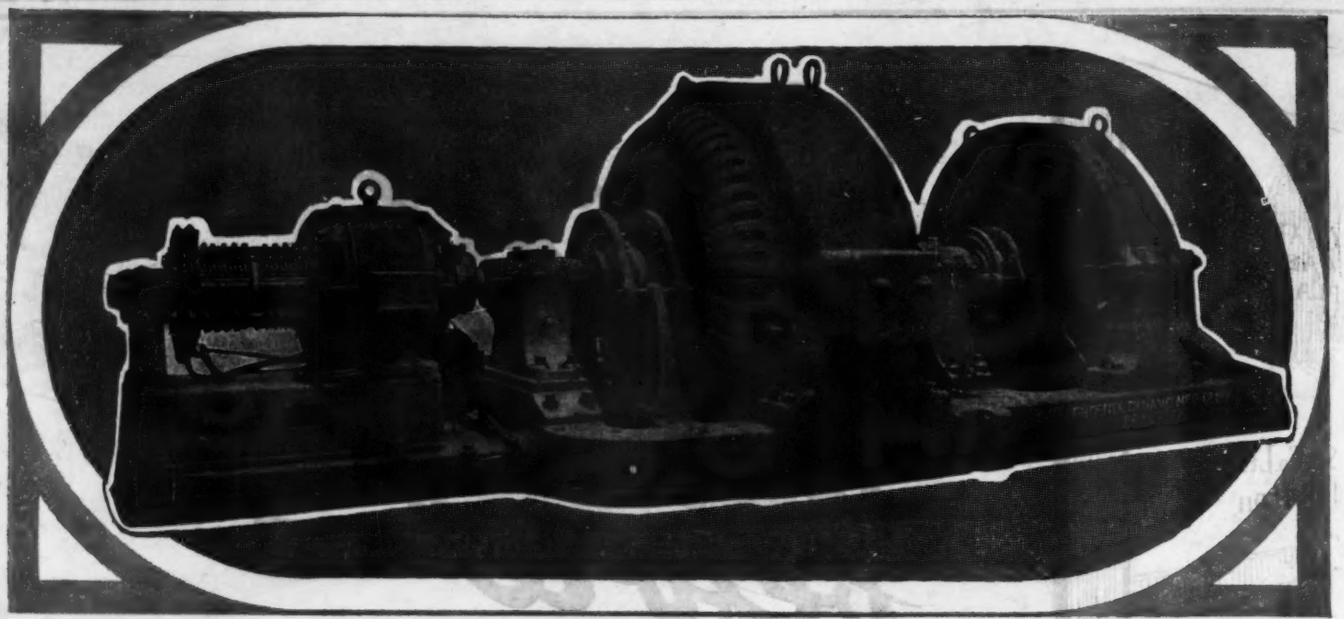

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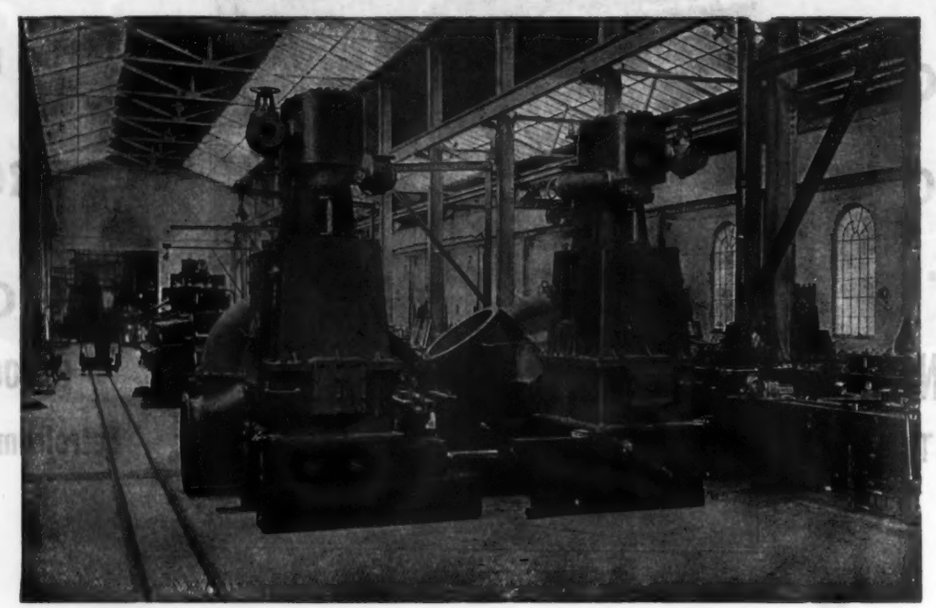

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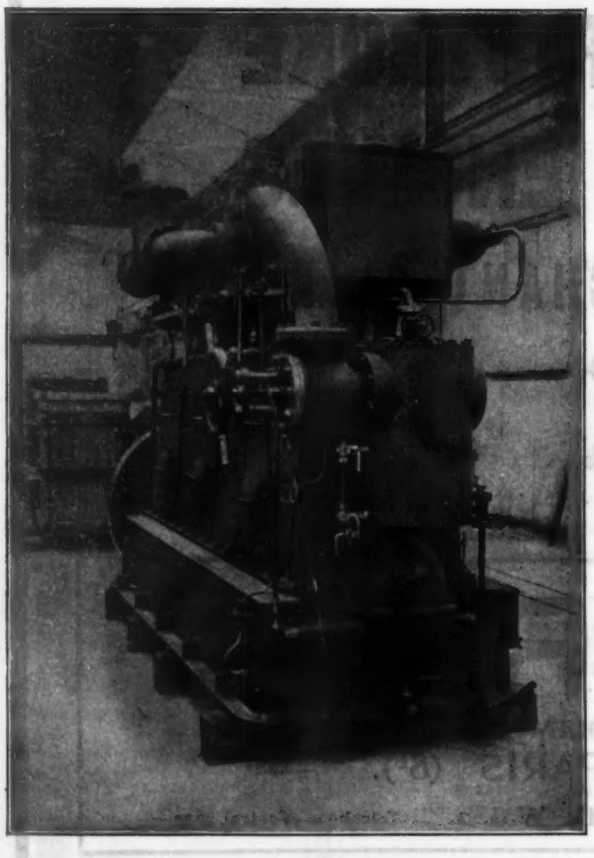

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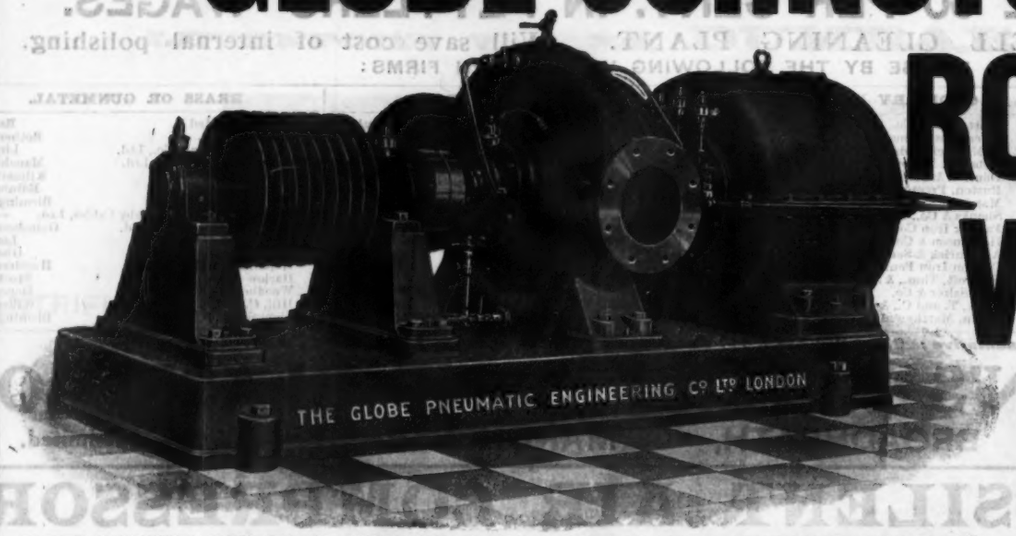

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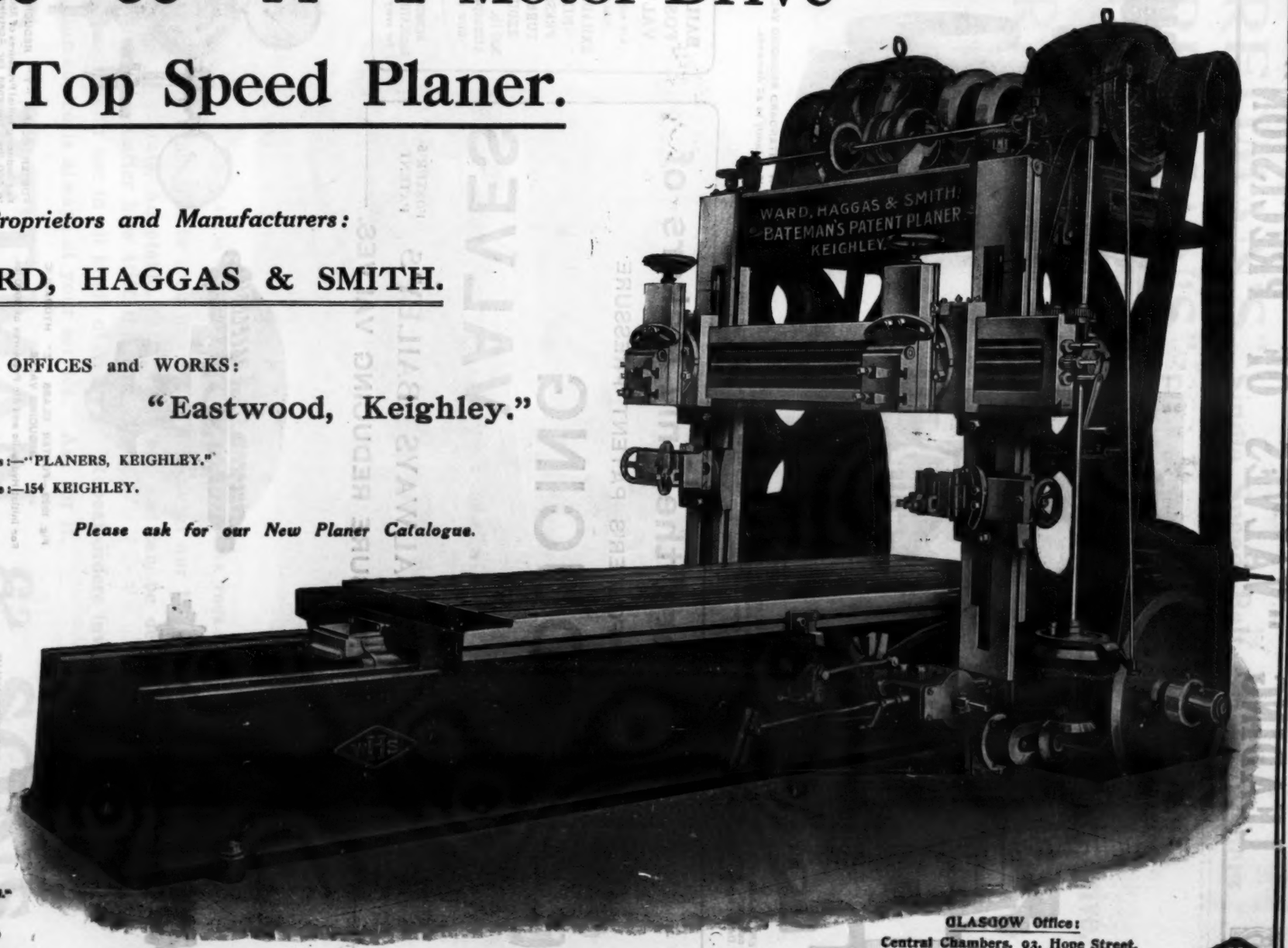

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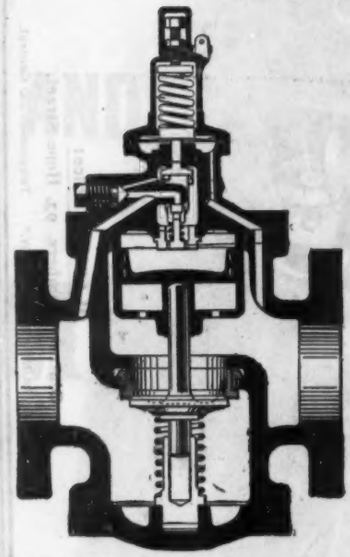

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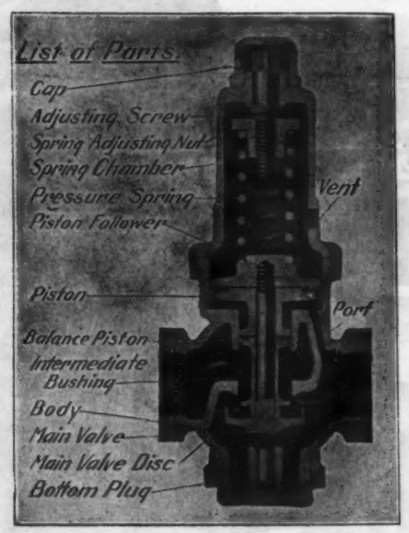

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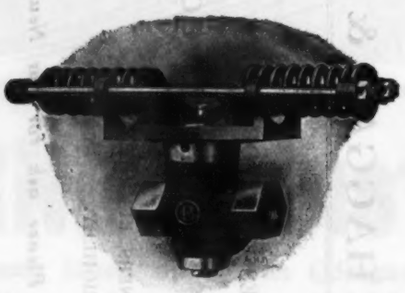

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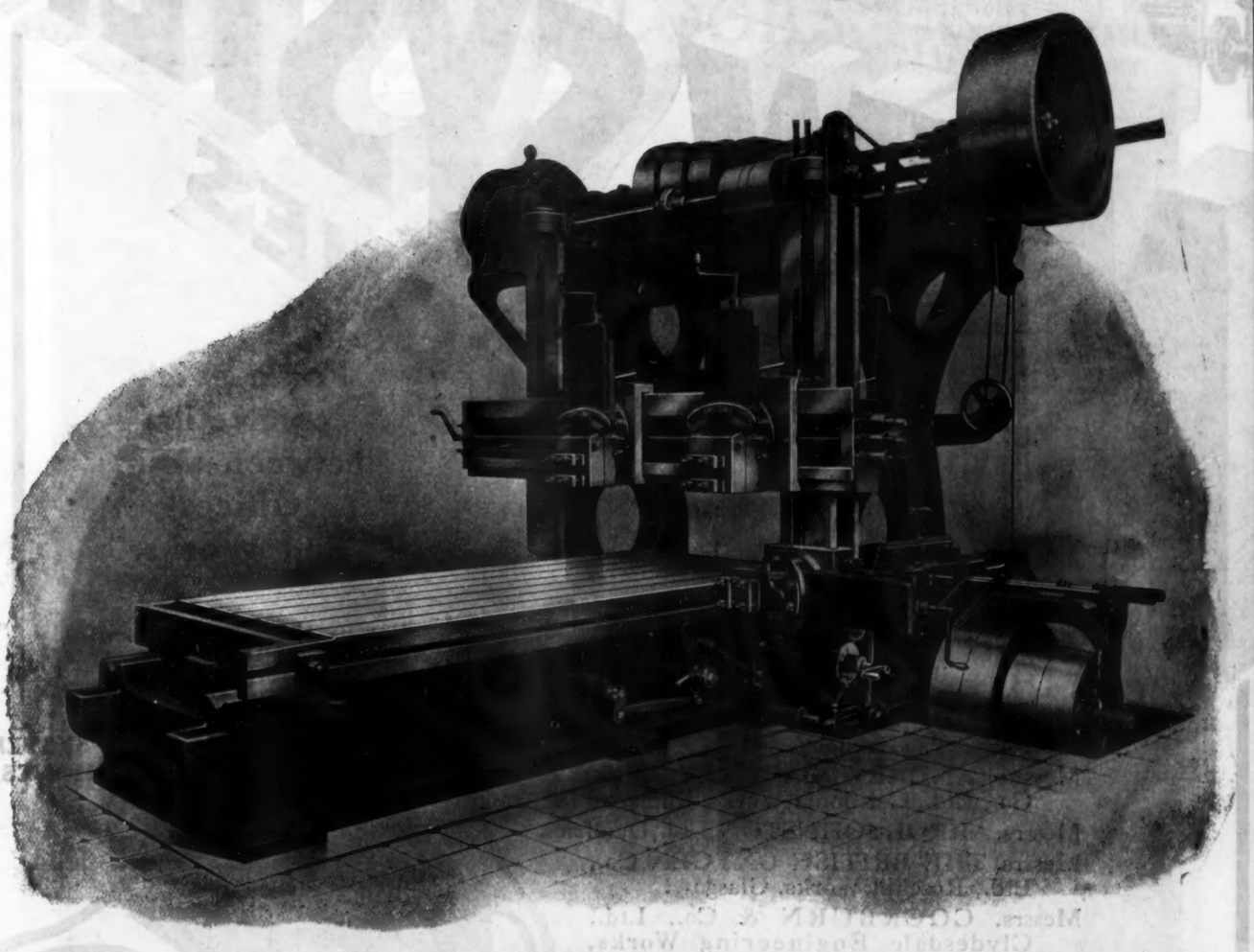

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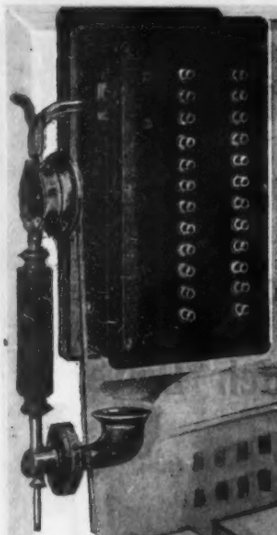

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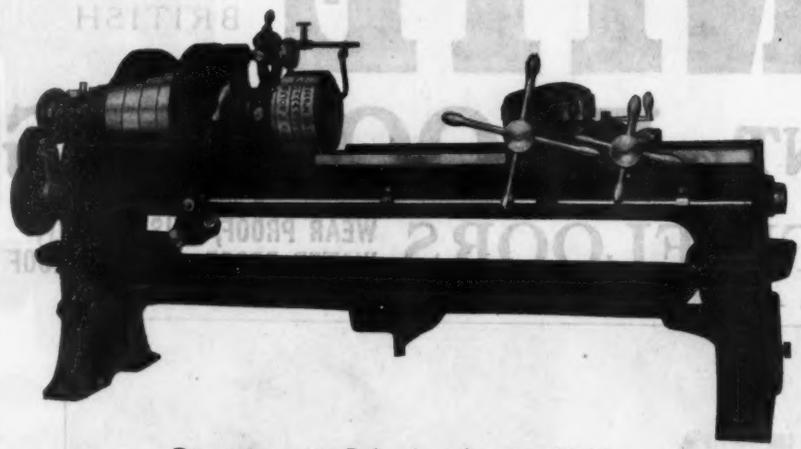

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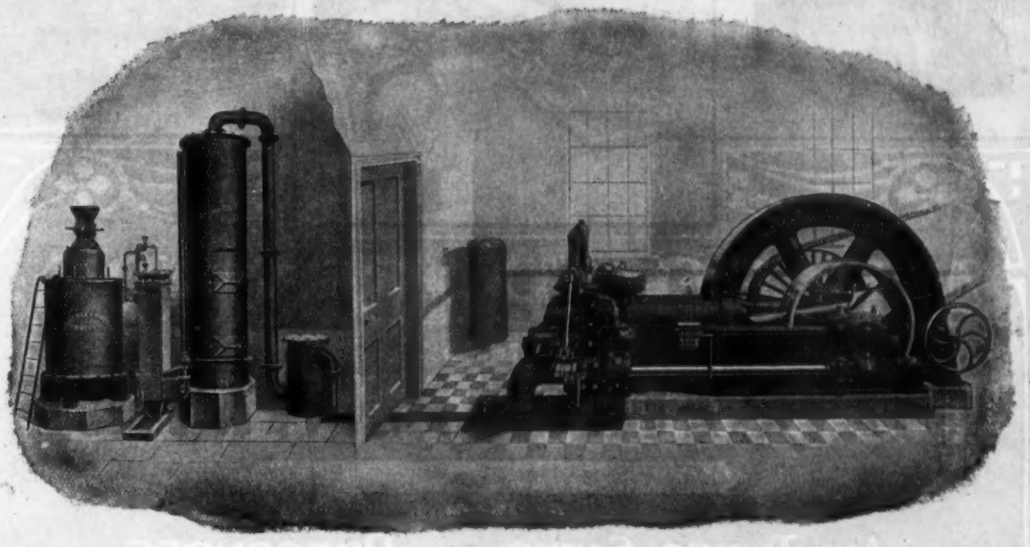

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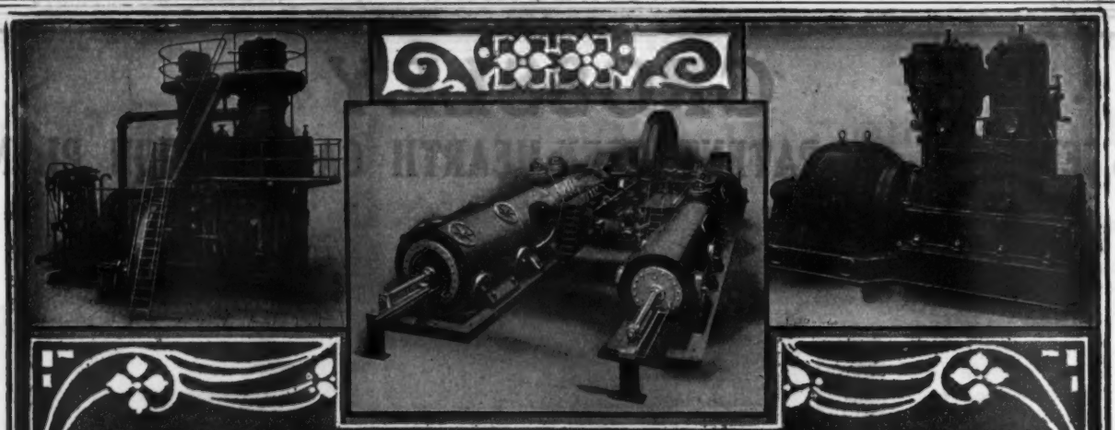

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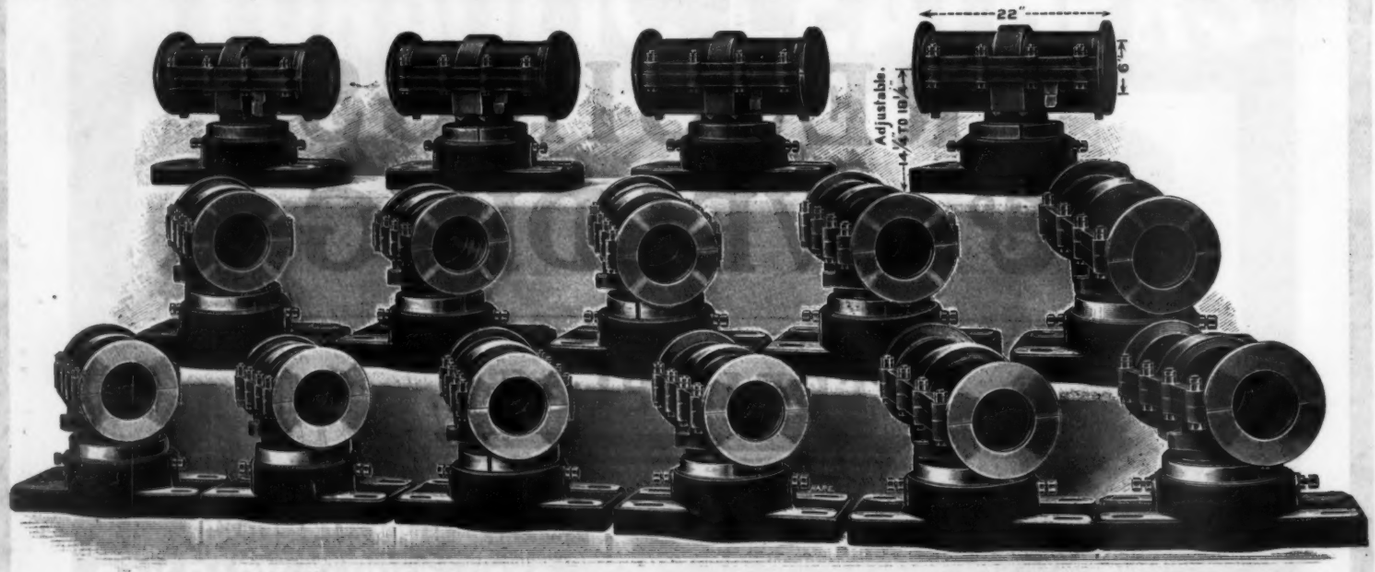

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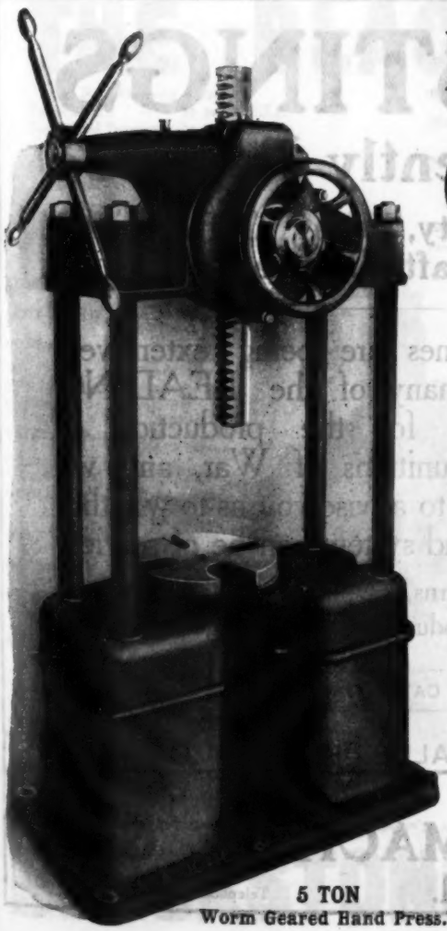

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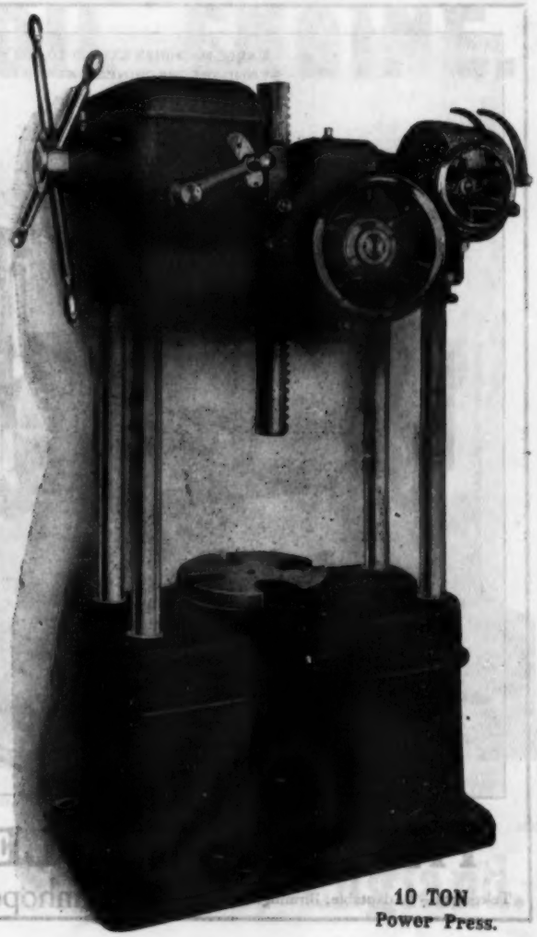

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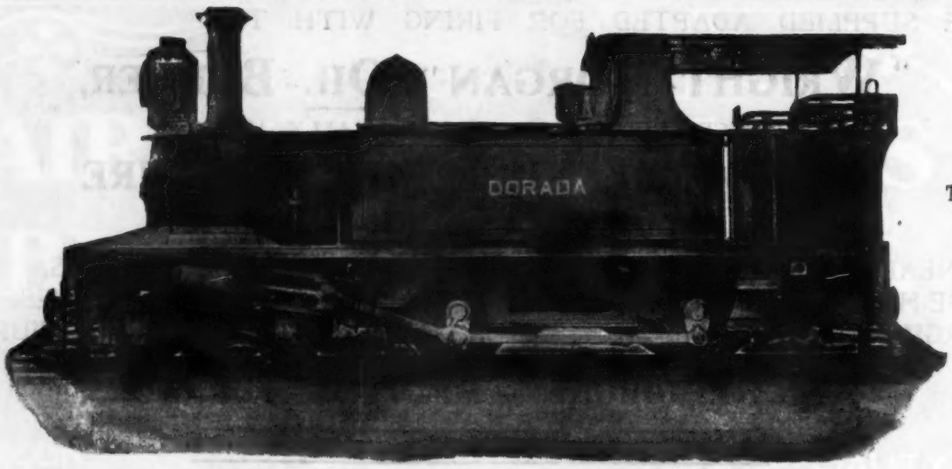

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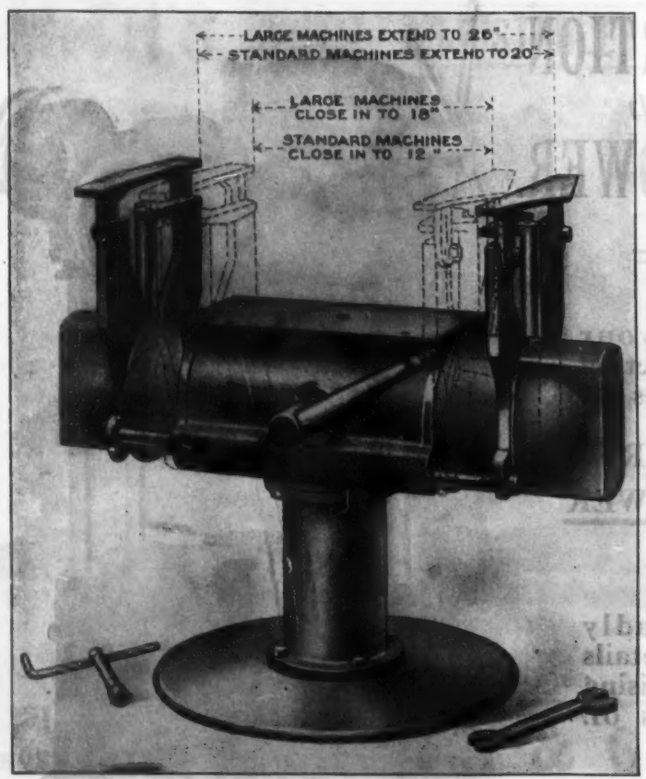
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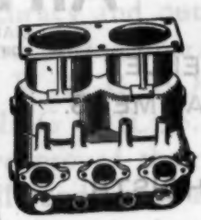

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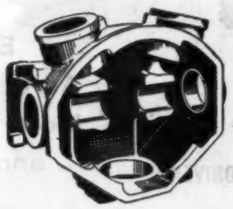

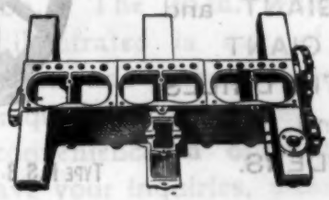

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Stationary Type.

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Portable Type.

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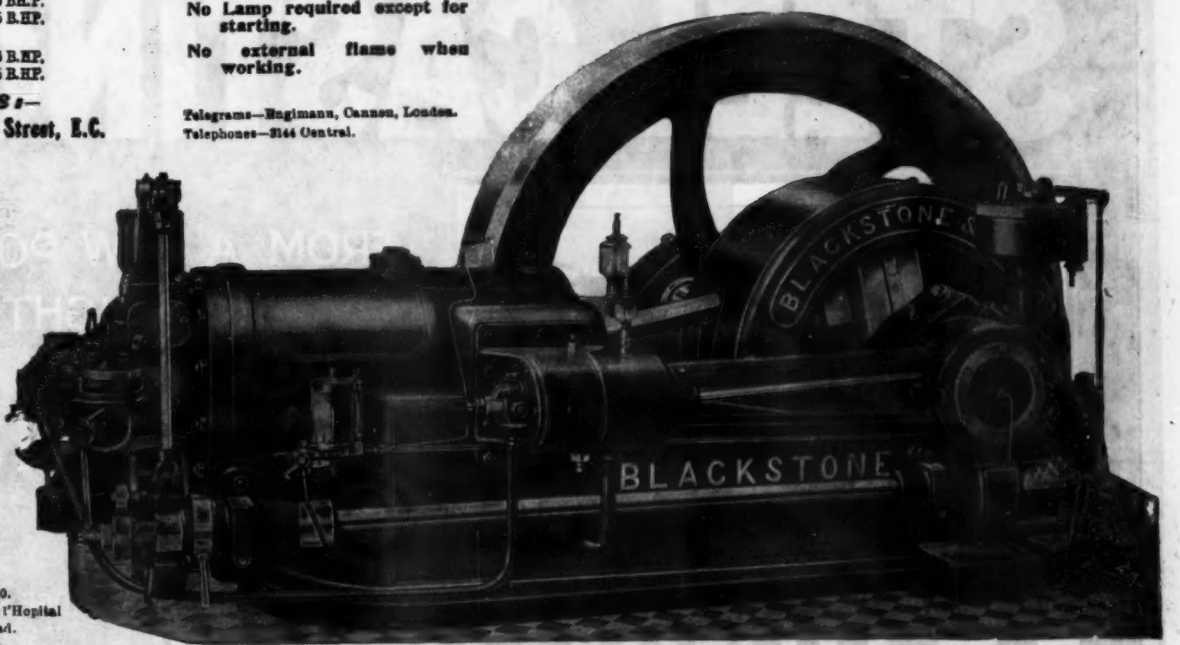

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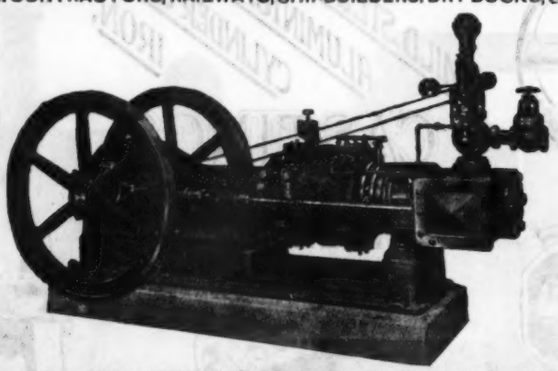

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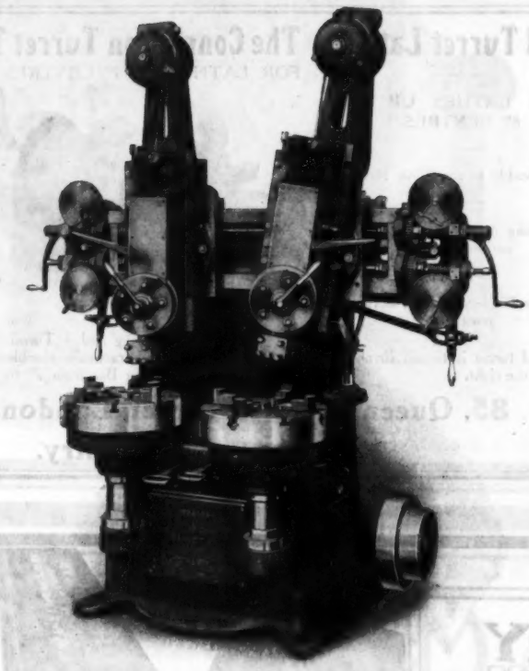

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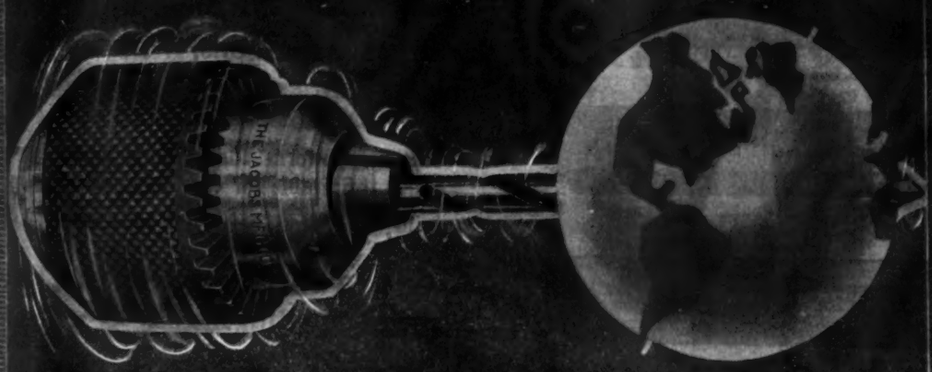
"Known throughout the World"



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(500,000 H.P. in Service.) 6203
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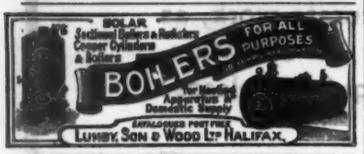

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Boilers to Suit.
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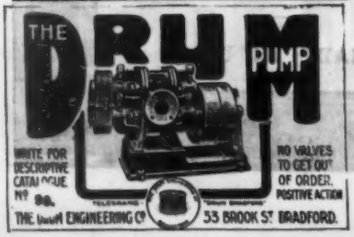
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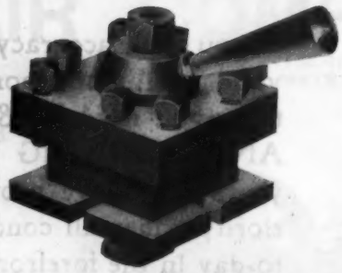

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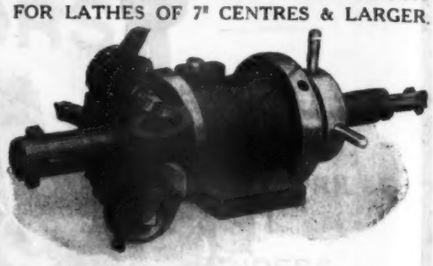

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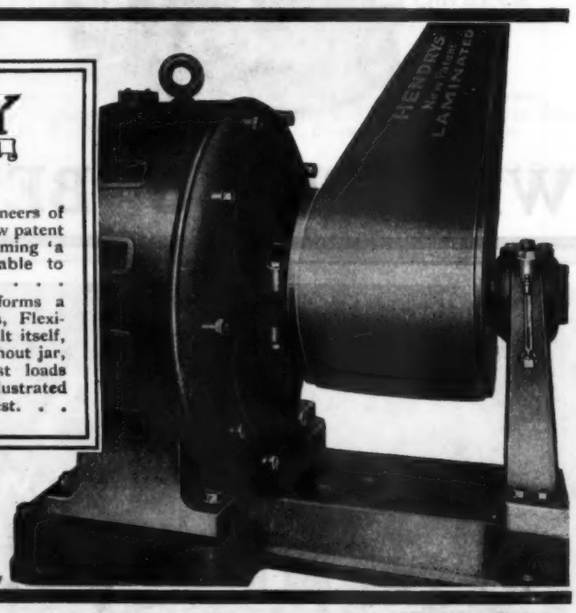

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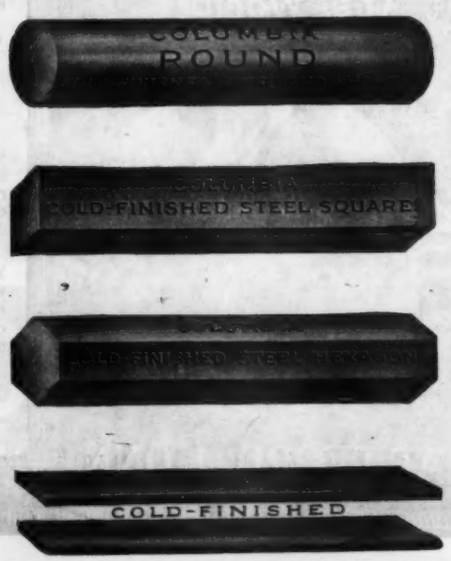

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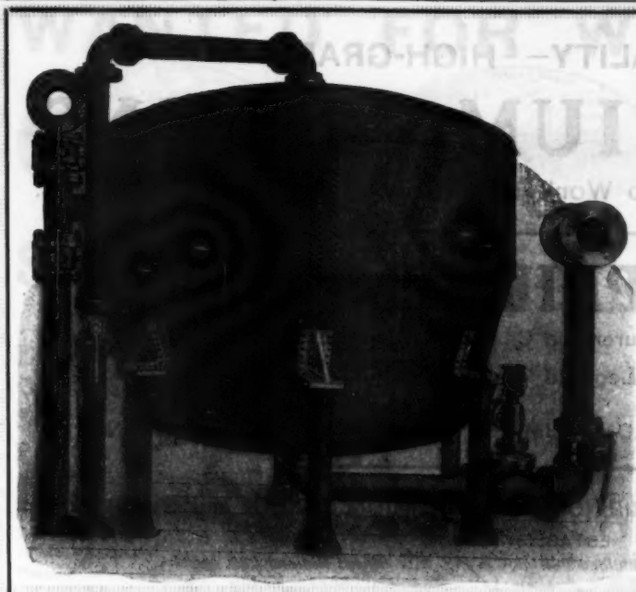

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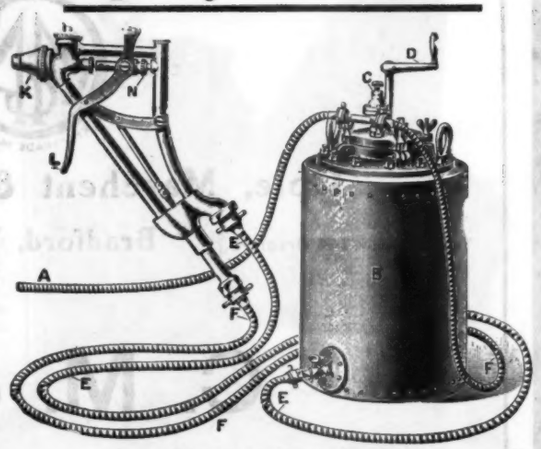

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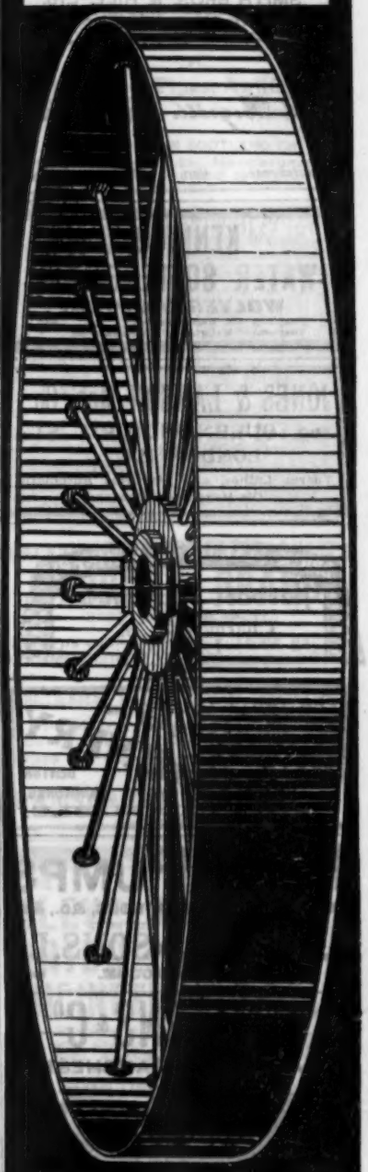

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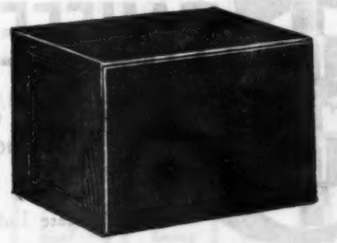

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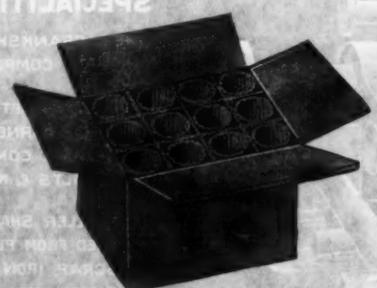

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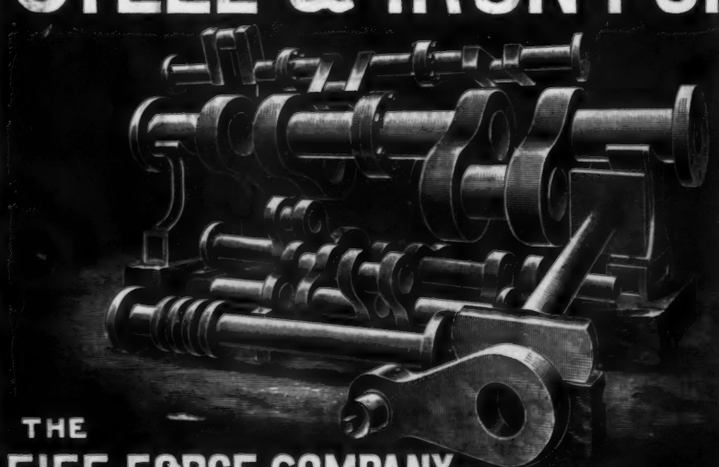

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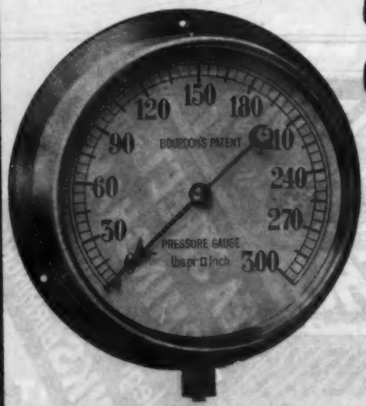

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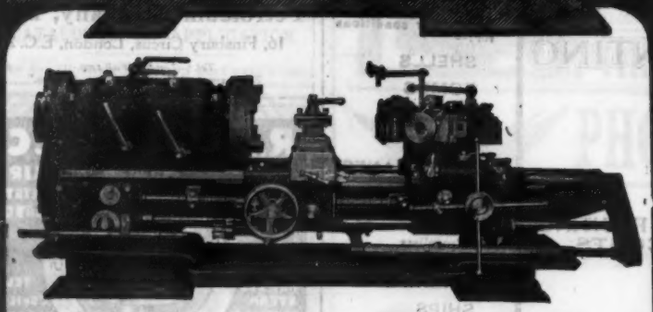

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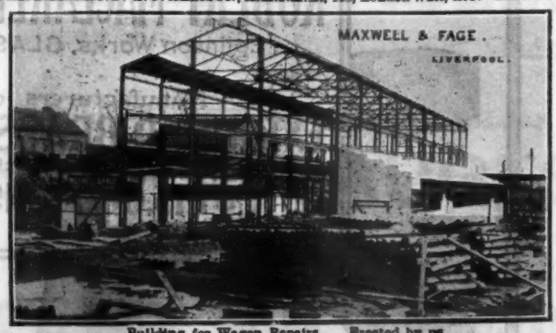

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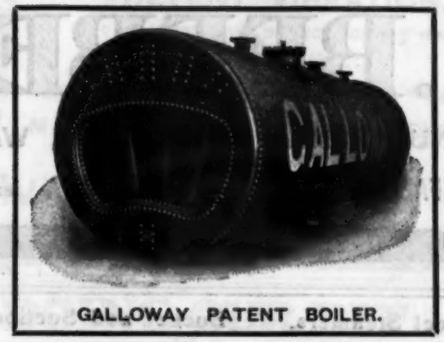

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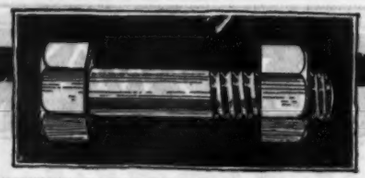

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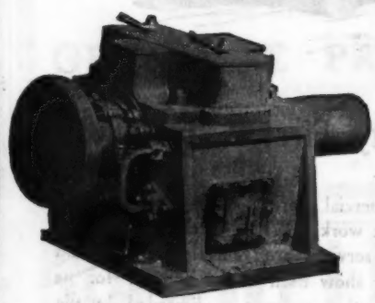

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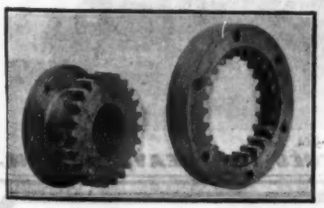
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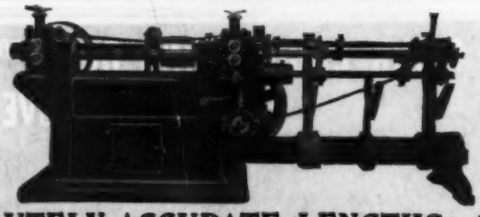

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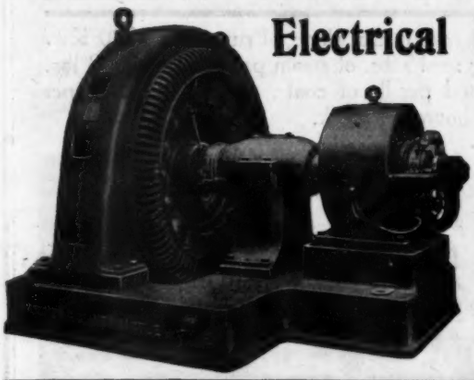

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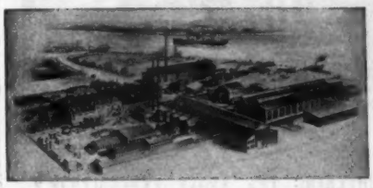

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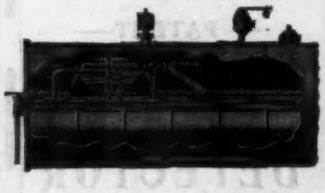

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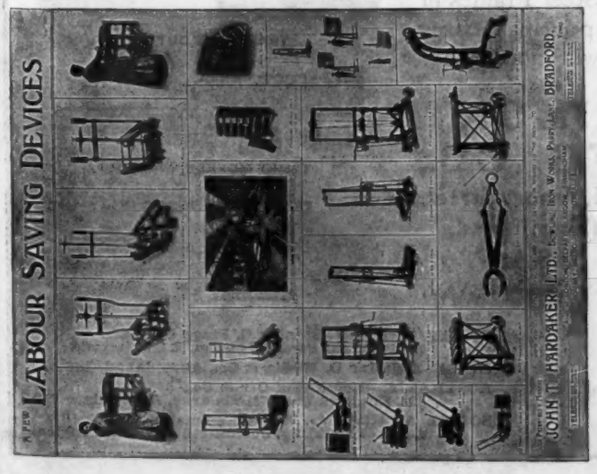

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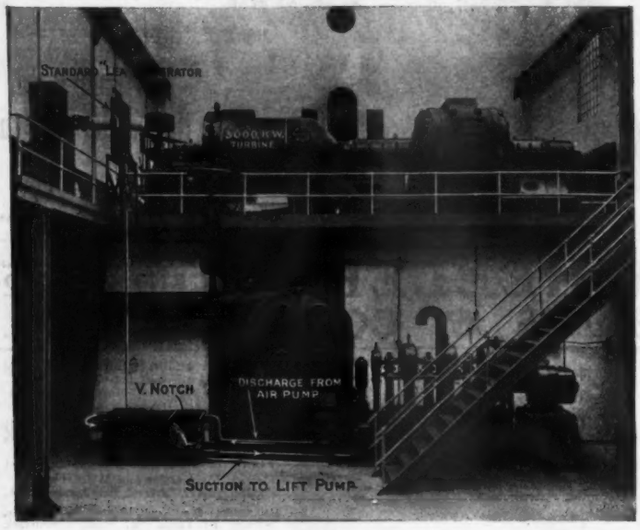

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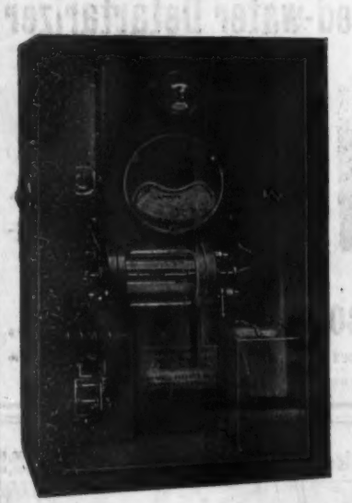

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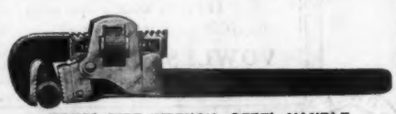

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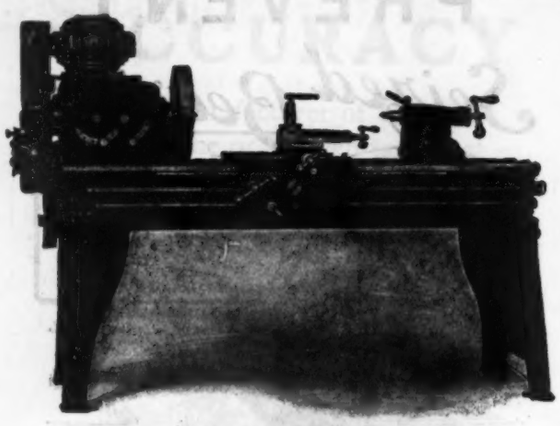

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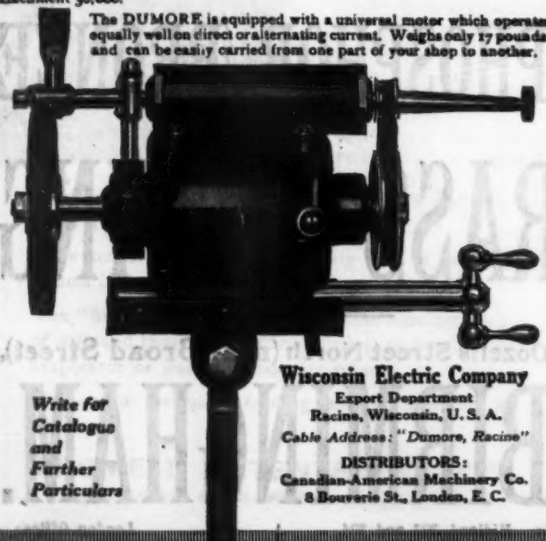

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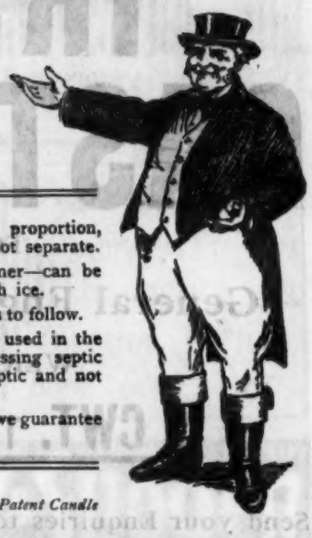

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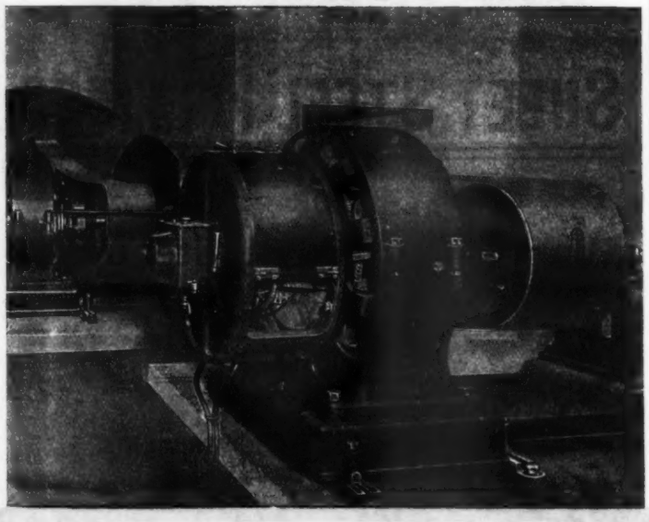

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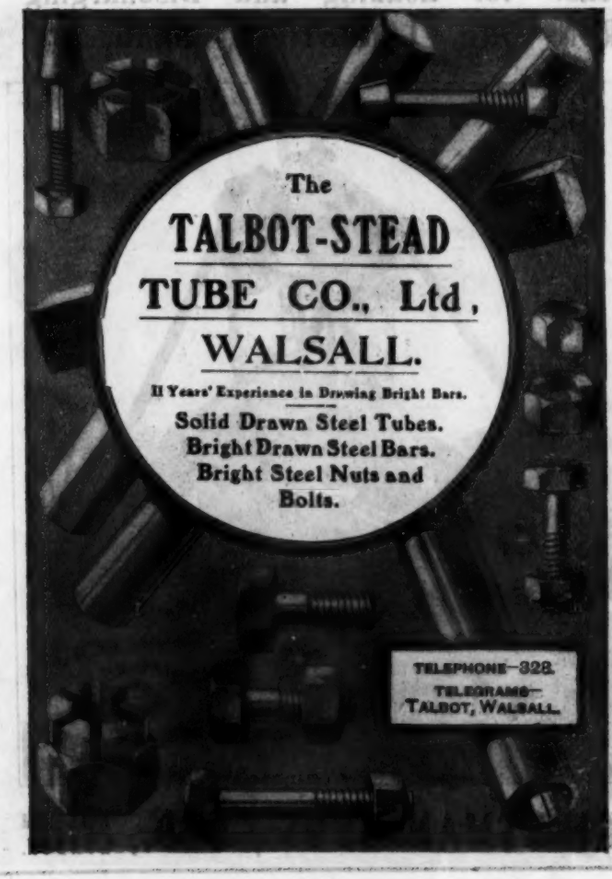

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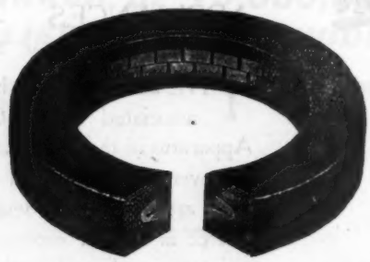

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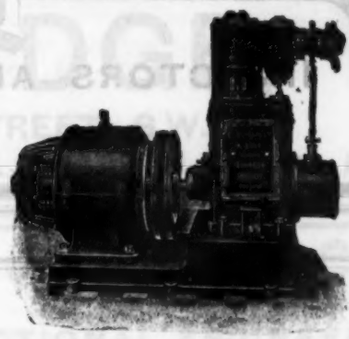

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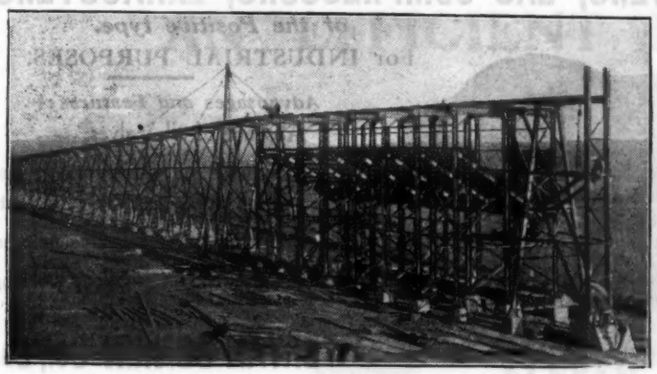

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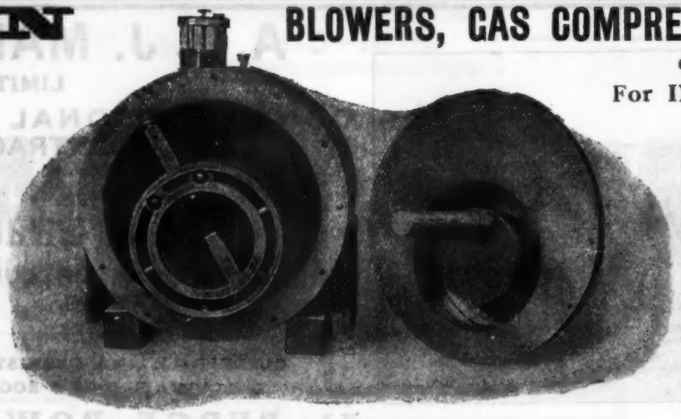

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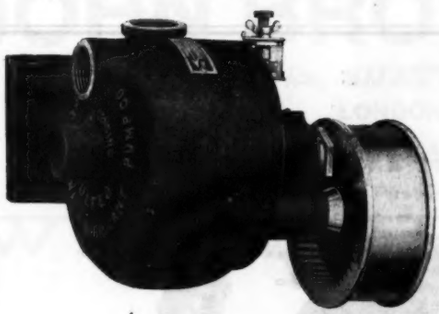

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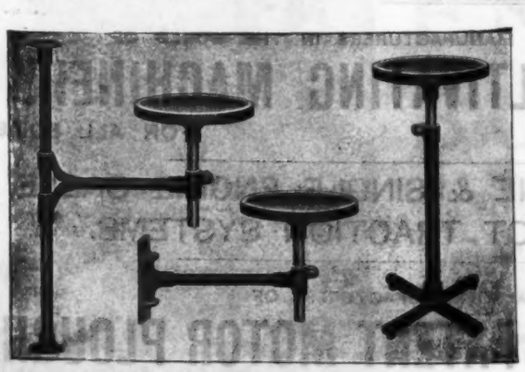

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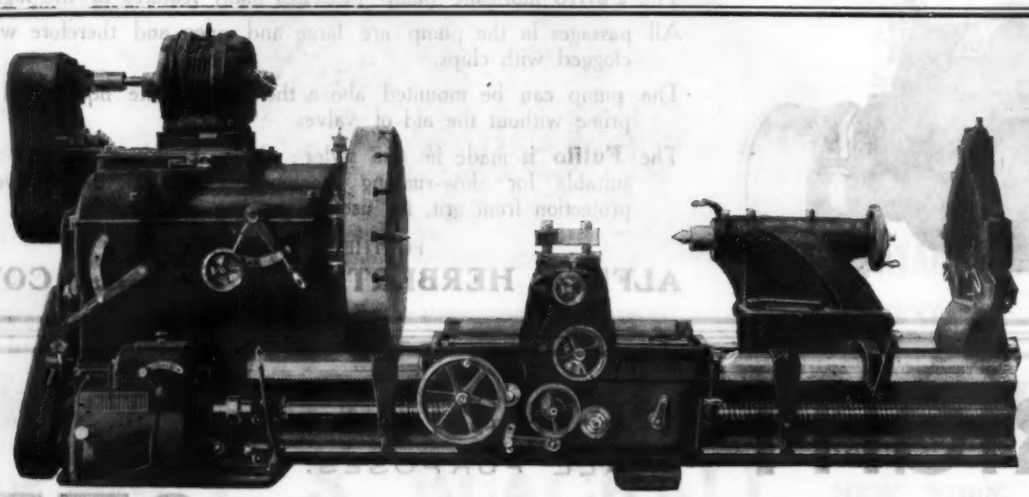

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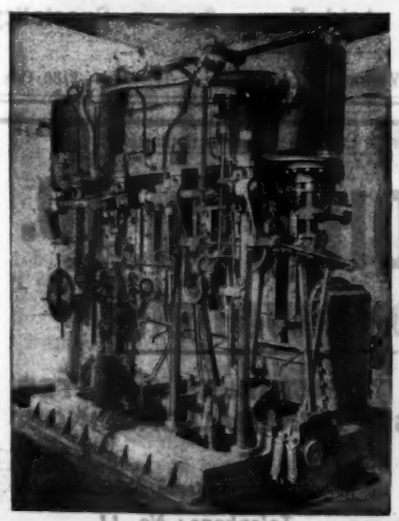

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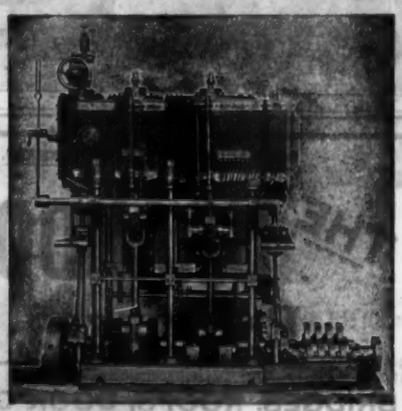

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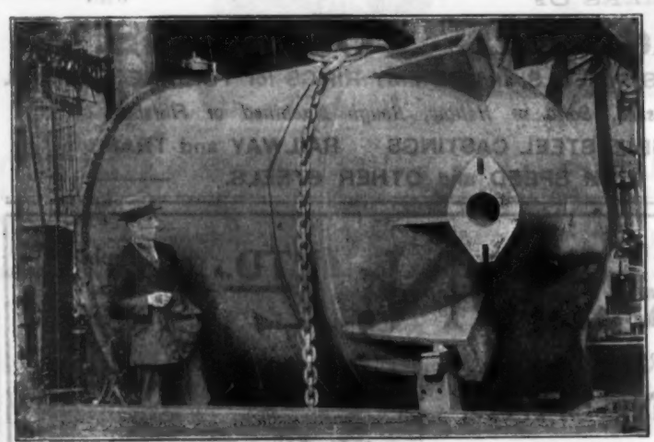

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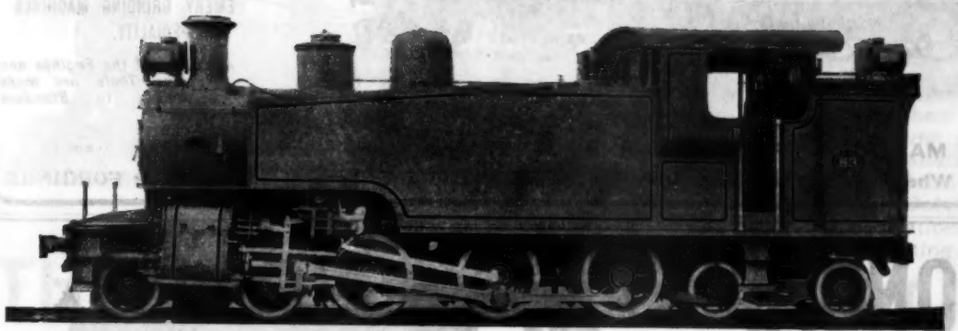

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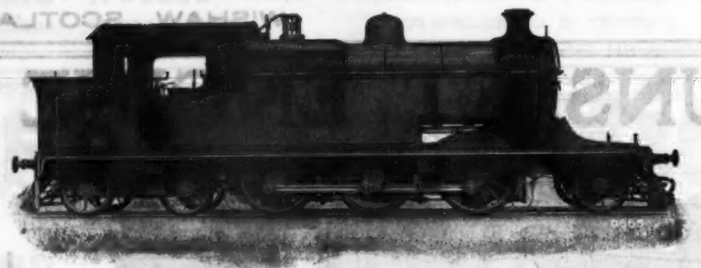

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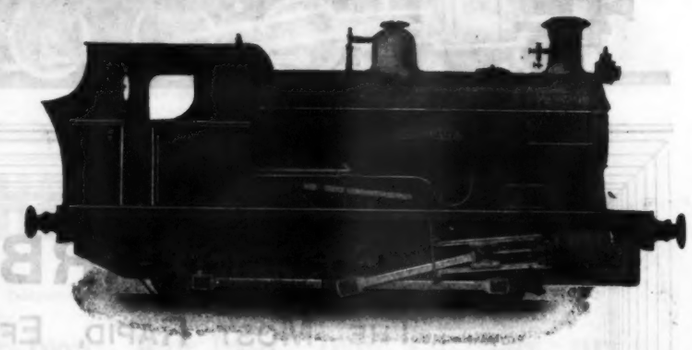

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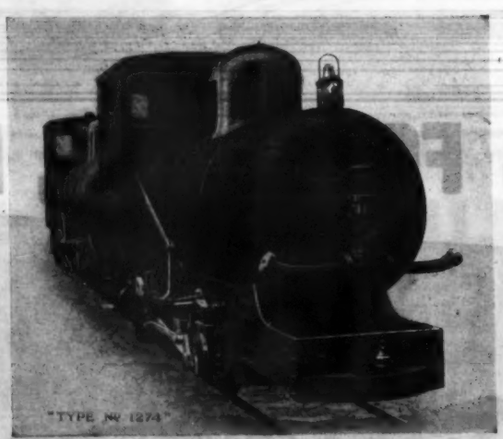

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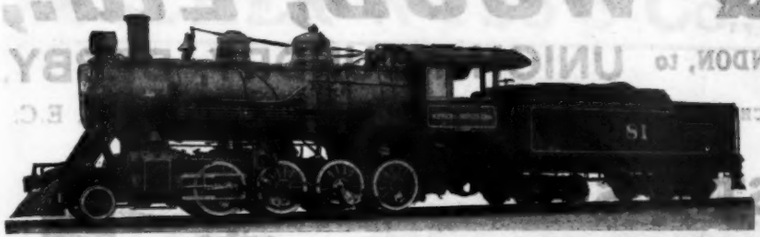

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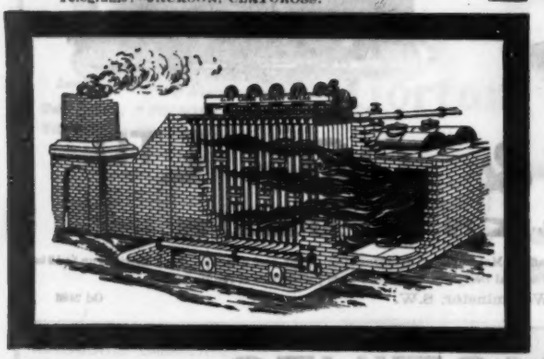

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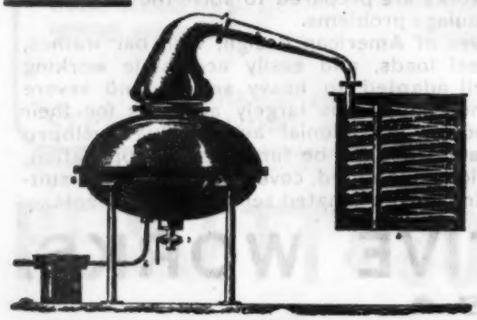

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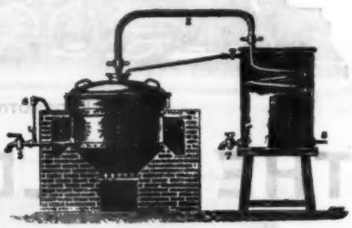

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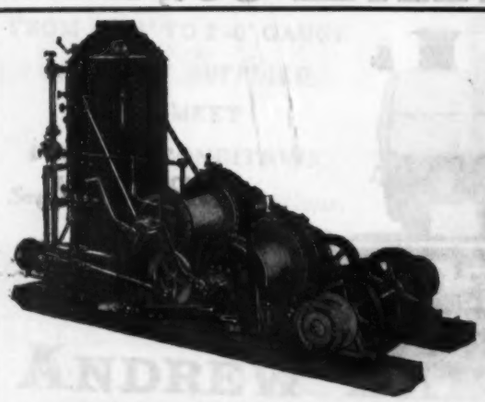

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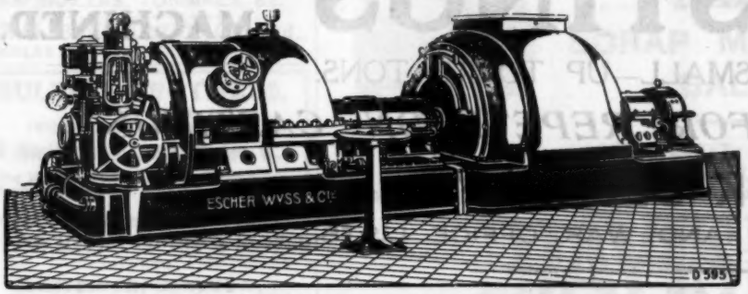

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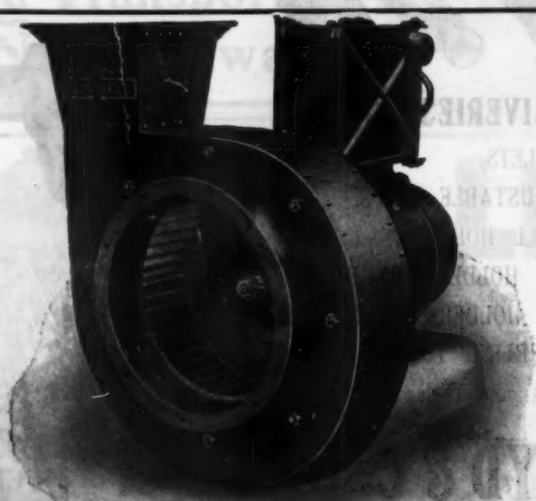

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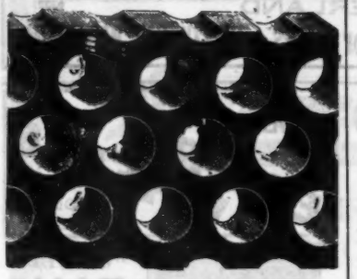

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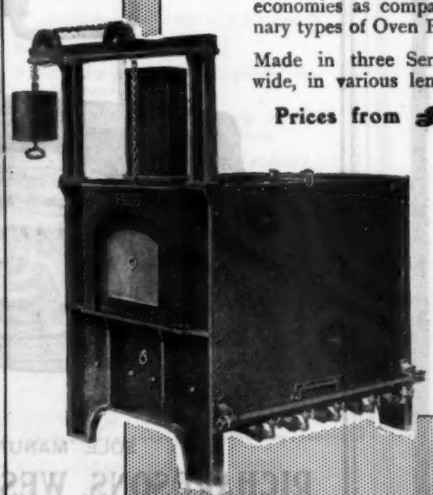

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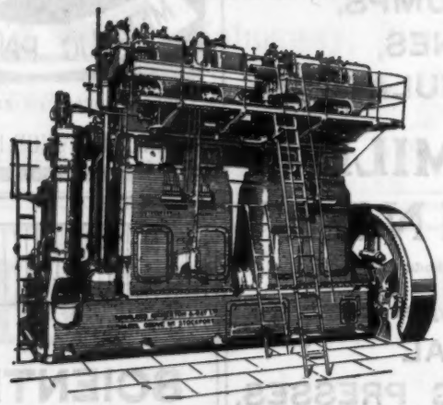

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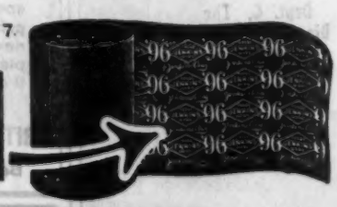

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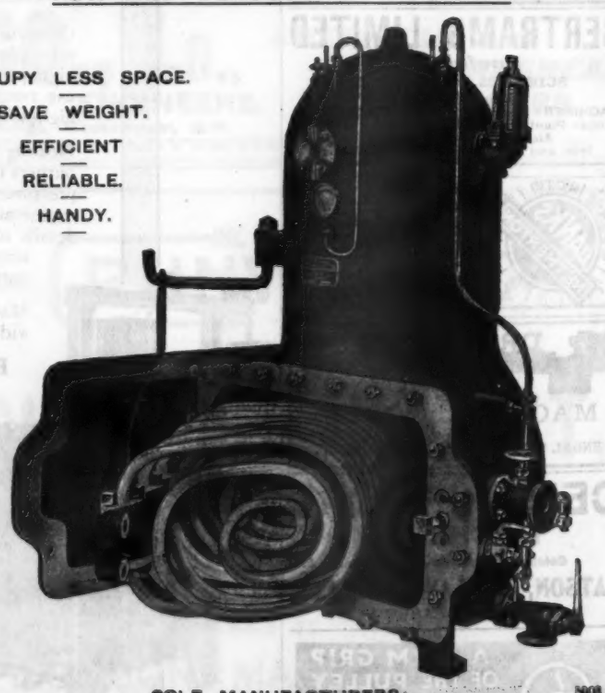

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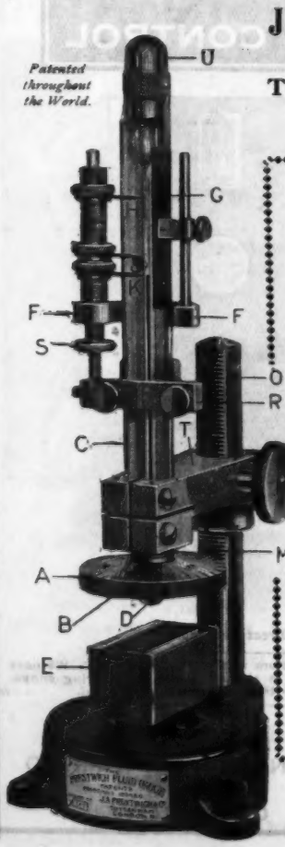

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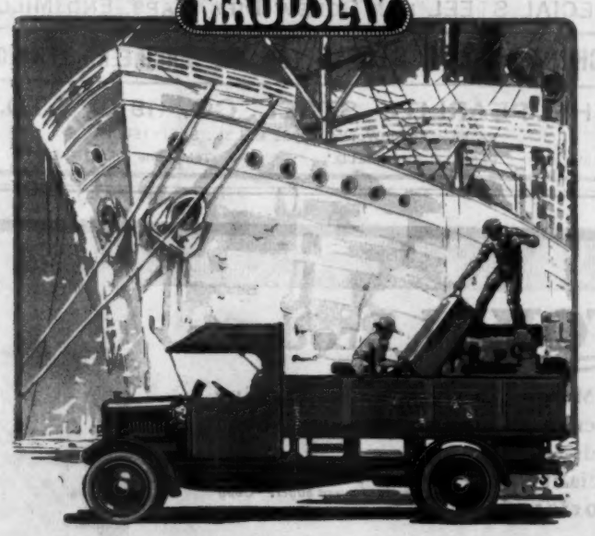

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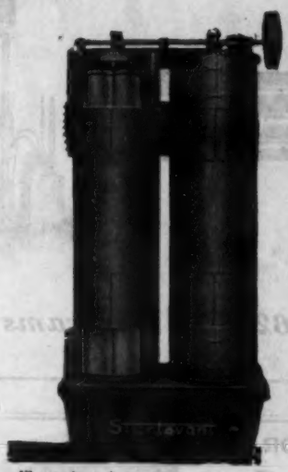

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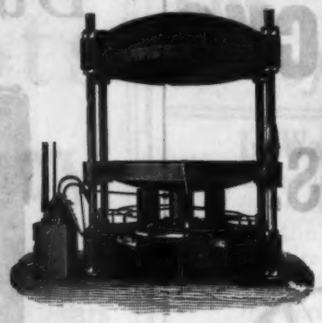

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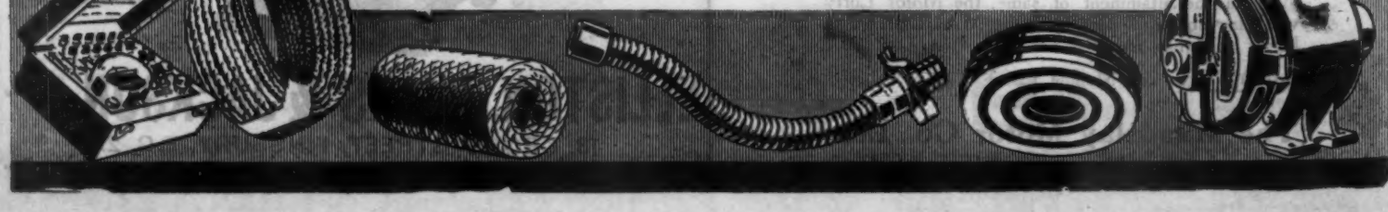

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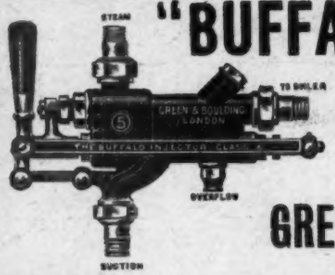

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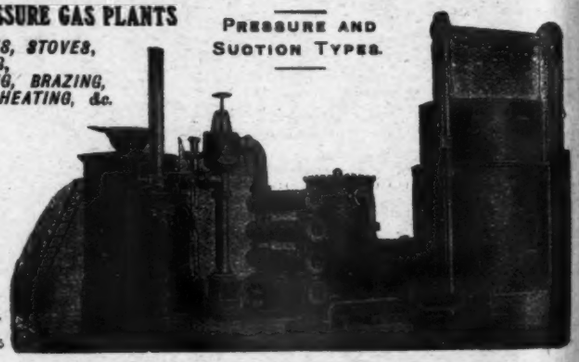

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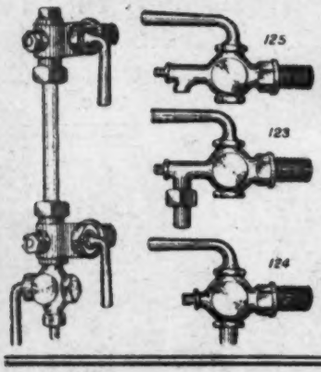

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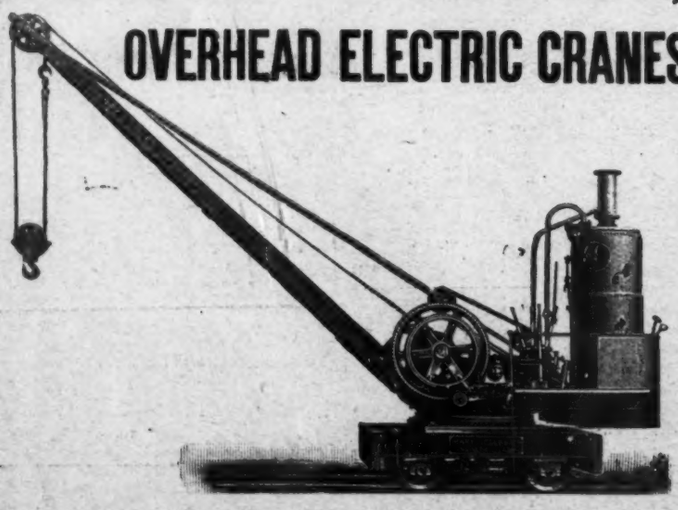

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